SWATH DESIGN MODEL FOR COAST GUARD APPLICATIONS

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ABSTRACT

A computer design model for preliminary design studies for the Small Waterplane Area Twin Hulled ship (SWATH) with special applications to the missions of the United States Coast Guard is developed.

The SWATH ship is described. Its application to missions requiring a stable platform and/or helicopter capabilities are discussed. The development of a computer design methodology is reviewed. Estimating relationships required for the design are developed based on existing designs and design studies. A listing of the program, examples of the input and output formats and a user's guide are provided.

This model is applicable to SWATH ships of 100 to 300 feet in length and of 300 to 5000 tons displacement intended for use by the Coast Guard.

The results of the computer model are compared with existing Coast Guard vessels and an earlier Navy design for a SWATH Coast Guard Cutter. General agreement with the Navy design program is shown in principal dimensions.

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CHAPTER I

SWATH OVERVIEW

The overall purpose of this thesis is to develop a computer design model for preliminary design studies for a particular alternative hull form which has been suggested for use in various missions of the Coast Guard. First the concept of the Small Waterplane Area Twin Hull (SWATH) hull form and its possible uses in these missions must be described.

The conventional monohull displacement hull form has been the sole configuration used by naval services and commercial ventures in the marine field for hundreds of years. Only in the last quarter of a century have other types of marine transportation configurations been developed in an orderly and scientific manner. In that time the hydrofoil boat has been developed into sea-capable small ships, the air-cushion vehicle and surface effect ship have been developed and conceptual designs for small ships studied and there has been increased interest in ships in which motions were controlled by reducing the size of the waterplane. The Small Waterplane Area Twin Hull (SWATH) ship has been the subject of a major effort by the United States Navy to develop such a small water-plane area ship.

The SWATH ship which has been the subject of the Navy studies and is the subject of this study can be described as a pair of torpedo-like hulls submerged underwater and connected through the water surface to a box-like bridge structure by one or two struts per hull. The SWATH ship is fitted with twin propulsors in the after ends of the lower hulls

and with various control surfaces similar to the diving planes of a submarine which can be used to control the SWATH's motions and attitude underway.

The low waterplane area ship concept is not new however, but until the 1960's it had received little attention. One of the first single-hulled low waterplane ships was patented by Lundborg[1]* in 1880. A twin-hulled low waterplane ship was patented by Blair[1] in 1930. A patent for a twin-hulled floating structure was granted in 1946[1]. In the late 1950's a shark-form was proposed by the Navy and studied at MIT by Mandel[1]. This hull form was similar to the Lundborg patent. In the late 1960's several student design projects[2] and a proposal by Frankel[1] were based on the twin hull low waterplane area concept. In 1969 the Netherlands Offshore Company launched a 1200 ton twin hulled drilling rig called DUPLUS[1, 3]. Litton Industries developed the TRISEC concept[1] during the LHA program concept design phase. TRISEC was a low waterplane area ship with non-cylindrical lower hulls, large lifting foils attached to the lower hulls, variable draft and a single large strut per hull.

Starting about 1969 the Naval Undersea Research and Development Center (NUC) and the Naval Ship Research and Development Center (NSRDC) began studies on the low waterplane concept. NUC[4, 5] designed a small test platform with two struts per hull and a displacement of 200 tons; NSRDC[6, 7] continued to extend the data previously gathered on catamarans with the rational step to the low waterplane ship. These design efforts

*Numbers in parentheses refer to References listed at the end of this thesis.

and studies led to the development of a series of computer based conceptual design studies for SWATH ships[8] and one full size prototype, the 80 foot, 190 ton SSP.

The SWATH ship has several advantages in operations. Because the size and locations of the waterplanes of the SWATH can be varied easily, a SWATH design may be optimized for minimum ship motions over a range of headings and ship speeds. Although the additional wetted surface area of the SWATH leads to higher frictional resistance values, the smaller waterplane area tends to reduce wave making resistance especially at high speeds. The low waterplane area and the fact that much of the ship's volume is well above the water in a box-like bridge structure also means that there will be little effect on speed and motions from a seaway. The large box structure leads to efficient utilization of payload space due to the rectangular plan of the spaces and to low production costs for the box. The large box also lends itself for utilizing large deck areas for helicopter landing areas or handling deck machinery or equipment packages.

As is the case with all design alternatives, the SWATH ship may have some disadvantages for the user. Because it is a different type of ship shape and because it will require more structural materials it may be a more expensive ship to build. The lower cost of its box structure and the smaller size vehicle required to meet desired seakeeping requirements when compared to a typical displacement hull may mitigate against higher cost arguments. The SWATH ship also tends to have a larger draft for a given ship size due to the necessity of submerging the hulls to gain the advantages of small waterplane area. The draft may be adjusted

while entering and leaving port by a variable ballast system if this is required and economically feasible.

The missions of ships are varied and the SWATH ship can be seen as providing a platform for several missions. As a stable ocean platform which could be fitted with a well (in the box) amidships and a suitable crane system, the SWATH seems well suited for oceanographic or underwater exploratory missions. The relatively deeply submerged hulls of the SWATH and the lack of wave making and bow emergences could make the SWATH a good platform for carrying sophisticated sonar equipment in an anti-submarine warfare mission. With the increasing sophistication of weapons systems, a stable platform can be useful for accurate location of targets. The SWATH might be called upon to carry radar or electronics equipment requiring a more stable platform. Certainly the large deck area of the SWATH box can be used as a helicopter landing platform and the SWATH could be used as a base for a helicopter detachment engaged in coastal surveillance and patrol or in patrolling or searching an off-shore area. The superstructure of such a ship could incorporate a hanger large enough to provide for intermediate level maintenance of the helicopters.

It is the possibility of using the SWATH ship as a mobile aircraft landing area which presents the most interesting application to the Coast Guard's changing missions and which is a primary motivation for developing the design model for SWATHs for Coast Guard applications.

CHAPTER II

WHERE CAN THE COAST GUARD USE A SWATH SHIP?[9,10]

Over the last twenty years the Coast Guard's missions have changed and its areas of responsibility have increased considerably. After the Second World War, sea duty meant weather patrols. Later Coast Guardsmen were sent to Vietnam to provide gunfire support and investigate and board hostile shipping. Now the enforcement of laws and treaties mission and the extension of our territorial waters along with the generally increasing offshore activity will require a Coast Guard presence further off our coasts for a larger part of the time.

Coast Guard air and sea forces have traditionally cooperated in carrying out Coast Guard missions in Search and Rescue, pollution control, fisheries patrol and icebreaking. Some of the newer cutters are equipped to handle helicopter landing and refueling in good weather but for the most part helicopters must return to a base ashore at the end of the mission or to obtain spare parts or do maintenance. The need for a truly helicopter capable ship will become more important as the area of responsibility increases and close coverage of changing areas along the coast becomes necessary. To provide this type of coverage with rotary wing aircraft of limited range, bases of their operation must be moved close to the operating area--helicopter bases must be moved to sea. These helicopter bases must be small enough and cheap enough to meet Coast Guard operational and budgetary constraints, yet provide a stable platform, adequate landing and maintenance area and quarters for an aircrew. The SWATH concept may provide an answer to this set of mission requirements.

The new mission of a Coast Guard patrol and enforcement vessel with helicopter capability might include provisions for speed sufficient to maintain position with a commercial fishing fleet, endurance for a three week operational patrol and a self sustained air group consisting of three or more helicopters. These requirements can be stated as a speed slightly in excess of 20 knots, a large helicopter landing deck, hanger, machine shops and parts storage areas for helicopter maintenance and repair, and an embarked crew for helicopter maintenance and repair, as well as the air crew.

Since there would be additional duties of such a ship either as a part of regular operations or as a vessel of opportunity, other equipment would also be desirable. Some type of weapons system would be fitted, perhaps including a medium calibre gun and associated fire control system. To be useful in a Search and Rescue mission, surface and air search radars would be required, and the ship should be able to tow a disabled vessel. If an anti-submarine warfare mission is envisioned, a sonar system should be fitted. Oceanographic equipment might also be fitted.

If a ship which incorporated all of the features listed above were constructed, it could be used for patrol and surveillance, law enforcement, search and rescue, oceanographic studies or anti-submarine warfare, and it <u>could</u> be efficient in all of these missions if it were a SWATH ship. A SWATH ship could move easily to the area of the patrol or search and deploy its helicopters for a coordinated search far from any land bases. If the location of the search was changed the SWATH could move to the new area while the search continued and land its helicopters at the new search datum point. Due to its improved seakeeping, the SWATH

ship could eploy its helicopters in rougher weather than could a similar sized displacement ship, thus permitting search or surveillance in deteriorating weather. With its installed sonar, stable platform characteristics and deployed helicopters the SWATH ship could be very impressive as part of an anti-submarine task group.

Thus, a SWATH ship appears to have many desirable characteristics for Coast Guard applications. The preliminary design phase of a new class of Coast Guard cutters should include an investigation of an alternative or several alternatives to the conventional displacement hull; the SWATH should be among these alternative concepts. To provide an efficient means of evaluating SWATH designs and comparing them to conventional designs one should design a computer ship design model. The next chapter provides an introduction to this ship design tool.

CHAPTER III
INTRODUCTION TO THE COMPUTER DESIGN MODEL

As more applications of the high speed digital computer are found in the ship design process, the naval architect has found it useful to develop a series of computer aided ship design tools known as ship synthesis models. Given a set of design requirements and a ship synthesis model, the ship designer can generate a feasible starting design which can be used as a baseline for future design studies or he can make minor changes in the ship's requirements to see how the ship's characteristics are changed.

The computer design model is particularly useful in the conceptual and early preliminary design stages. The computer generated ships can be used to evaluate trade-offs early in the design process. Sets of principal characteristics of the feasible designs as functions of the input cases and estimates of various operating parameters can be used effectively in the evaluation of designs worthy of further design effort as well as furnishing the designer with the necessary baseline data for further design studies.

However, the outputs of the computer model are not optimum ships. Optimum design, even a very good design, requires many feasibility studies and trade-offs. These studies and trade-offs would require considerable time and the efforts of several designers if they were accomplished by hand and often a number of good alternatives will be overlooked because of the feelings of the design staff that the idea is not particularly good and the lack of time to investigate all alternatives. The computer is the only way to make many studies quickly and economically.

Since its output is directly related to the estimating parameters within the model, the computer ship synthesis model gives consistent and rapid answers. Proper documentation indicates how the estimating relationships were derived and the limits assumed for validity. Only a change to the program itself can change the relationship of the output to the input parameters. By providing for the program to accept several groups of data and calculate answers for these data, the designer can get quick answers to changes in requirements and to the "what if" question. This ability to respond rapidly to changes in requirements or input parameters and the fact that each decision within the computer program is made consistently means that a manager can readily evaluate the impact of a particular requirement on the ship design as a whole and make a rational decision on how to proceed--to fix the ship dimensions and requirements and proceed to more detailed design or to ask for more information from the computer model.

Both the United States Navy and the Coast Guard have ship synthesis models which they can use. During the 1960's and early 1970's the Navy developed several models including the DD07 model used as a basis for Goodwin's[(11)] Cutter Model which extended the Navy destroyer model down to 150 foot Coast Guard vessels and included Coast Guard standards. Many of the estimating relationships used in the model under development here for the Coast Guard SWATH have come from this source. The Coast Guard also is interested in developing design models for other types of special purpose ships. A Buoy Tender model is now being developed at Coast Guard Headquarters with some inputs from a similar student project at MIT. Although the entire ship system for an icebreaker is not included in a ship synthesis model, there are several aspects of icebreaker design

which have had computer applications such as resistance calculation and costs.

The object of this study is to develop a simple model for SWATH ships in Coast Guard applications. The usefulness of the SWATH concept in a Coast Guard application was discussed in the previous chapter. The Coast Guard's in-house design capabilities would be enhanced by adding the SWATH model to the Cutter Model. Because of the similarity of purpose it is desirable that the format of the SWATH model resemble that of the Cutter model and the options, input parameters and output information be similar. Chapters V and VI describe such a model.

CHAPTER IV
SWATH MODEL DEVELOPMENT

The basis for all computer ship synthesis models is the development of estimating relationships which can be written into the program. The relative accuracy among studies and the ability to compare various alternatives rapidly is more important than absolute accuracy of the result. For this reason estimating relationships are based on existing design data, the published literature and in the case of the SWATH, on summary data of U. S. Navy conceptual and preliminary design studies[8].

In developing the estimating relationships used in this model, the author has been guided by: a)dependence of the estimating relationship on the most significant input variables; b) compliance with present Coast Guard design practices; c) reasonableness of the results; and d) shortcut estimates often resulting in linear relationships. As there is relatively little data on the SWATH configuration available, comparison of recent Coast Guard designs and the Navy SWATH designs to gain estimating relationships applicable to both has been attempted when design principles indicated this was a reasonable approach. Some relationships are merely developed from drawing a "mean" line through scattered data. Thus, the estimating relationships which are developed are rather crude and the model can only be expected to estimate at the ship systems level. Therefore, the outputs of the model will include such elements as total structural weight, total volume of machinery and required electrical generating capacity. Total arrangements area is computed in the program but no attempt to arrange the areas in the ship is made. Because the

SWATH tends to have a rather box-like arrangeable area there should be many alternatives for the engineer to consider in validating the computer output by hand. No attempt is made by the program to calulate trim either, because this calculation would be influenced considerably by arrangements.

The SWATH model will check a set of input variables to determine if they form a feasible solution to the ship design problem. The model checks for a balance between weight and displacement, for a balance between space required and space available, for a balance between energy required and energy available, for acceptable levels of longitudinal and transverse metacentric height and checks to insure dimensions within the range of reasonable SWATH design. The requirement for a weight displacement balance is important in this type of ship because of its low waterplane area and reduced ability to carry loads without large changes in draft. The volume balance may force the addition of a second level in the box structure--an enormous additional volume which has an impact on the weight. Metacentric height checks will form the basis for the strut shape and separation. These variables also affect resistance calculations.

The inputs required for the SWATH model are in general a description of the vehicle mobility performance parameters and a selection of various options to be used. The payload description must be sufficiently detailed so that the weight, relative vertical center of gravity, required deck area, electrical power requirements and cost are available for compilation by the model. The size of the crew must also be input to the model. Vehicle mobility performance can be described by the maximum calm water speed,

endurance speed and range. The options of the model include varying length, the type of machinery, the hull material, the margins and whether the horsepower is to be computed or if the maximum speed for a given horsepower is to be determined. A full description of the program inputs and available options for the SWATH model is contained in Chapter VI which describes the program and its development in more detail and in Appendix A which is a users guide for the program.

The output generated by the SWATH model must be suitable to demonstrate the feasibility of the design. Tabulated data and ratios are available for the engineer to use in validating the design without further calculation. The output lists the areas to be arranged and make it possible for a design team to lay out a rough arrangement and verify that there is sufficient space for all the requirements. The output also provides the engineer with some method of assessing the optimality of the solution based on some criterion. Often the only important optimality criterion is acquisition cost; for this reason the SWATH model includes a simple cost estimating routine for the first ship acquisition cost. The output of the model can be used as a baseline for carrying on the preliminary design phase. Either an optimal design can be chosen and the data used for the input to the preliminary design team or a series of designs can be run to produce a range of results from which optima can be gleaned by cross plotting.

However, it is important to emphasize that the SWATH model will produce a feasible solution only and that it is not an optimum solution. The manual design process allows the engineer to guide the selection of alternatives which appear to be attractive. An interactive computer design

process would allow the engineer to guide the computer in doing the lengthy calculations. The model does not allow this interaction but by entering several data sets which seem attractive, letting the computer do the solution and then letting the engineer evaluate the results and request more alternatives in a later computer run, the model can almost be used as the interactive tool, and the engineer will sense the optimum parameters.

It is also important to emphasize here that this model is limited in the cases which it can cover. Its basic limitations are listed in the table below:

TABLE I
SWATH MODEL LIMITATIONS

Ship Size	
Length	100-300 feet
Overall Beam	30-100 feet
Displacement	300-5000 tons
Performance	
Speed	6 - 33 knots
Structural Design	
Number of Decks in Box	1 or 2
Material	Steel or Aluminum/Aluminum Deckhouse
Number of Struts/Hull	1
Hydrodynamic Design	
Hull Type	Cylindrical/Ellipical Nose/Parabolic Tail

The remainder of this thesis is arranged as follows:

Chapter V gives an overview of the SWATH model and explains the options of the program.

Chapter VI goes into more detail on each of the subroutines of the program and explains the derivation of estimating relationships. This chapter is not necessary for the understanding and use of the program and may be skipped by a user who is not interested in the details of the program.

Chapter VII gives an evaluation of the program and a comparison of its output with existing Coast Guard design and Navy SWATH design for Coast Guard applications. Chapter VIII contains conclusions and recommendations.

Appendices A and C contain information on the input format with a guide for punching input data cards and a sample of the output format, respectively. Appendix B is a listing of the program.

Before using the program it is recommended that at least Chapters I through V, VII and VIII and Appendix A be read. Chapter VI will be valuable to those who wish to study the evolution of the program or to change it.

CHAPTER V
GENERAL DESCRIPTION OF THE PROGRAM

This chapter is intended to give the reader and potential user of the SWATH model an overall description of the computer program and the method of executing the feasibility solution but it does not discuss the details of the development or use of the subroutines or estimation methods used in calculations. The reader is referred to Chapter VI for more detail on the subroutines. This chapter, however, gives an indication of how the subroutines are used in the total program.

An attempt has been made in the development of this SWATH model to use the same program organization and input data set information as was used by Goodwin[11] in the development of the cutter model. Program execution is controlled by Subroutine XECUTE unless data for a new case is to be read into the program. Subroutine XECUTE calls the subroutines as needed and the appropriate calculations are made to return data for storage until the feasibility study is completed and the data is ready for output. This subroutine also controls the checking of some data, notably horsepower requirements, against the range of validity of the model, printing out error messages and providing the iteration loops for weight and center of gravity. The control of program execution is shown schematically in Figure 1.

A logical organization of the program is shown in Figure 2. Note that Subroutine XECUTE is omitted from this figure as it merely guides the execution of the various subroutines as the program moves around the logic-loop. The inputs, types of calculations accomplished and the outputs from each of the program segments will now be described in general terms.

FIGURE 1: PROGRAM CONTROL ORGANIZATION

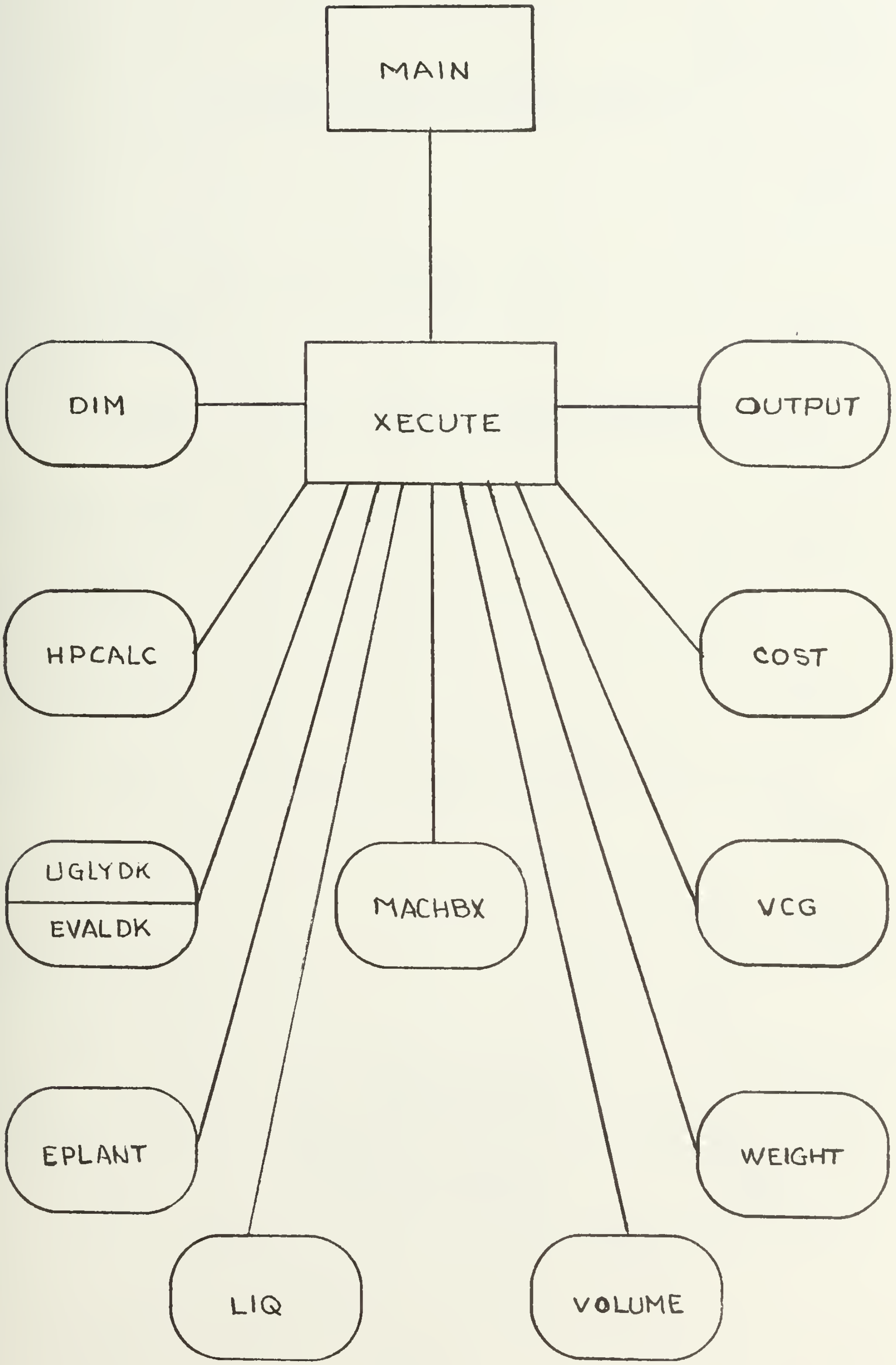
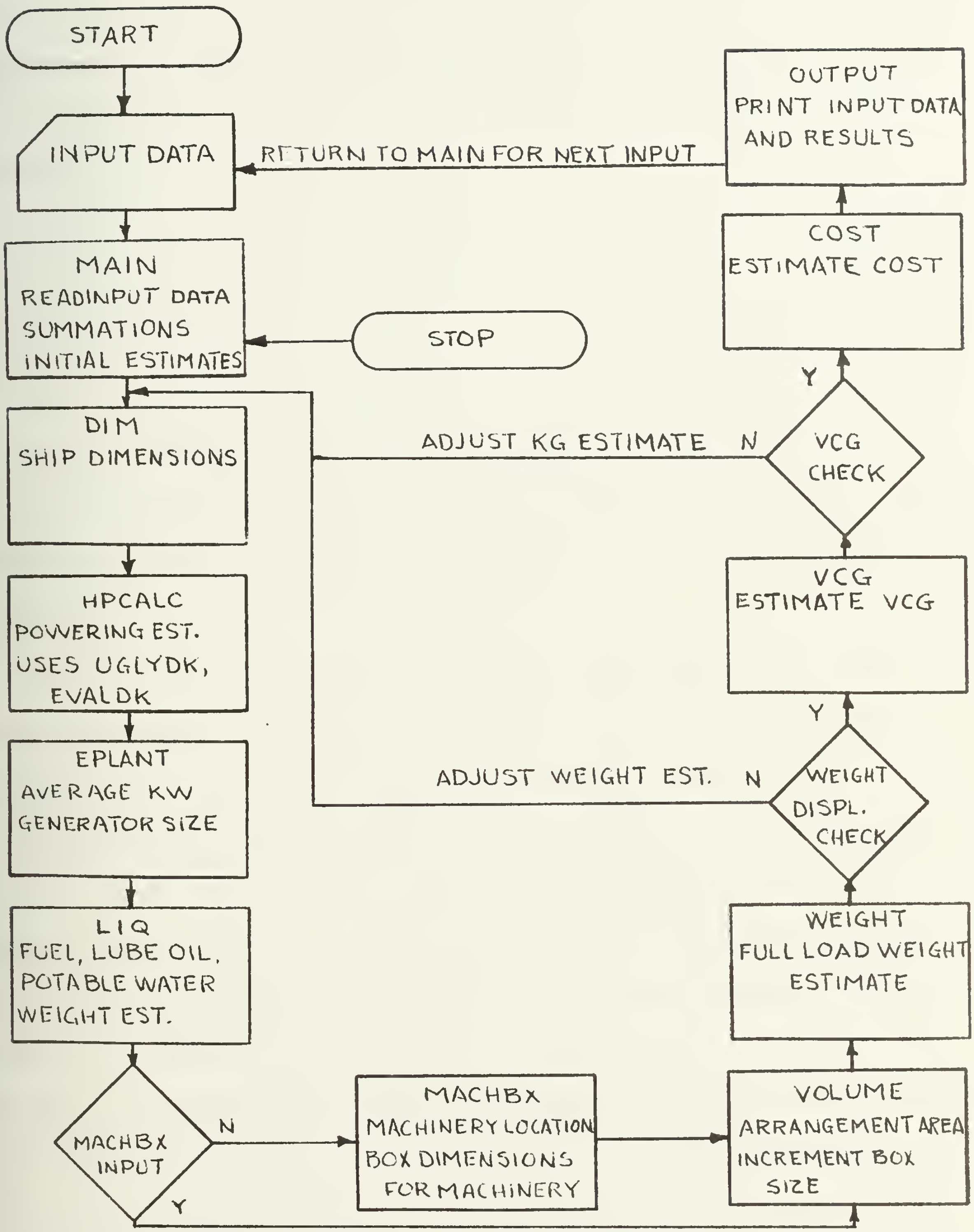


FIGURE 2: PROGRAM LOGICAL ORGANIZATION



The program begins with the reading of data in the MAIN program. The primary purpose of MAIN is to read in the input data set, but MAIN also is used for summing payload item weights, area requirements and costs. The initial estimates of displacement, vertical center of gravity location and cubic number are made by MAIN.

Once the input data set has been read and stored and initial estimates have been made in MAIN, Subroutine XECUTE is called. XECUTE then controls the execution of the program until a feasible solution is output or until a program constraint is violated. In either of these cases control will then be returned to MAIN for the reading of another data set if one exists or the termination of the program if there is no more data. XECUTE controls the program stepping through the other routines shown in Figure 2.

The first subroutine called by XECUTE is Subroutine DIM, which provides the basic dimensions of the entire ship. Its inputs are the desired length of the ship and its approximate displacement. The subroutine sizes the hulls and struts, checks to make sure that submerged volume equals displacement, checks longitudinal metacentric height against SWATH practice, checks transverse metacentric height against SWATH practice, adjusts the dimensions to insure acceptable values of metacentric heights, positions the struts on the hulls and generates an initial size for the box structure connecting the hull-strut combinations. This dimensional information is stored for use in other subroutines.

Two options are available for the next calculation, speed and power prediction. For both options the program first computes points on a speed-power curve which are stored for future recall. The program

then uses a spline cubic curve fitting subroutine, UGLYDK, to pass a curve through the points of the speed-power curve. For the first option, if the maximum speed for the ship has been specified and the horsepower required to meet this speed is desired. Another subroutine, EVALDK, is called which evaluates the horsepower curve at the given speed. EVALDK is called again to provide the value of horsepower at endurance speed. These two values, maximum horsepower and endurance horsepower are then returned to storage. If, on the other hand, the speed made good for an input horsepower value is desired, the program will compute this speed using an initial estimate and an iterative procedure. The control of this iteration is in Subroutine XECUTE. In this option the endurance speed is an input so the required horsepower is evaluated in the same manner as for the first case.

The generation of the horsepower curve is based on a potential flow and empirical method developed by Chapman[12] and simplified and modified for use in this model. The evaluation of the horsepower curve is done using the spline cubic curve fitting routines of Kerwin[13].

The next subroutine, EPLANT, calculates the size of the electrical plant to be installed. The required inputs are the size of the crew, the estimate of cubic number and the input values of electric loads. The average electric load is calculated and the required generator size is determined. These values are stored; the average load will be used for determining the fuel requirements of the generators and the generator size will be output.

Then the weights of fuel oil, lubricating oil and potable water are calculated in Subroutine LIQ. The endurance horsepower required

calculated by HPCALC, the number of crew, and the endurance range are inputs. If the specifications of the machinery plant are inputs, the calculations for fuel weight will be based on those inputs. If only the machinery type is input, lubricating oil requirements and fuel oil requirements will be estimated based on the machinery type and the horsepower range.

If the machinery plant is specified, the location and size of the main machinery spaces will be given and the program will skip to the VOLUME Subroutine. If the maximum speed is an input, however, the program will call Subroutine MACHBX and the location and dimensions of machinery spaces will be estimated. The inputs to this subroutine are the dimensions of the ship, the machinery type and the horsepower. Based on the size of main machinery components and the horsepower, the prime movers and propelling units are placed in the hulls or in the box and the dimensions of the spaces are estimated.

The next subroutine called calculates the volume which is required and adjusts the ship dimensions to provide sufficient volume to meet the requirements. Because the SWATH volume is primarily in the hulls and the box, both of which are simple geometric shapes, the volume calculation for this type of ship is not as complex as that for a conventional displacement ship. Machinery and tankage are assumed to occupy the hulls. The struts are not desirable as arrangement area because they are long and narrow, so it is assumed that one platform deck is available in the struts and that the remainder of the strut volume is uptakes, access, overflow tanks or non-arrangeable voids. The box and deckhouse are useable for arrangement volume without restriction. The

inputs to the subroutine are the ship dimensions, crew and the weights calculated previously. First the liquids are accounted for in tankage volume. The machinery space volume in the hulls is then determined. Steering gear and control fin machinery spaces are provided in the hulls. The total hull volume available is checked against that required and additional volume is provided in the struts for overflow tanks if the hulls are too small. If the overflow tanks are also too small the program returns an error. Then the deckhouse volume, box volume and strut volume are calculated. The volumes are converted into arrangement areas by dividing by an average deck height. No sheer is assumed in these calculations. The deckhouse is checked to make sure it meets the requirements. The remaining machinery space volume is placed in the box as an arrangement area requirement. All other arrangement area requirements are determined and summed. The required arrangement areas are calculated based on empirical data from other designs and on input area requirements. By varying the size of the deckhouse or by adding another deck to the box structure, the available area can be made larger than the required area. In the SWATH configuration excess area is quite likely because the additional deck in the box should extend from end to end to gain structural strength. Partial raised decks are not considered in this model. If too large a deckhouse or more than two decks in the box are required an error message is generated and the program cycles for new input data.

Once the volume of the ship has been calculated, the weights of light ship weight groups and the load items can be determined. Because of the lack of data on SWATH ships only one digit weight estimates are made in

this model and they are printed out in the output. The most important variable at this time is the full load displacement which must be compared with the initial estimate. If the difference is more than 9 tons, a new estimate of displacement is made and the program returns to the DIM subroutine to estimate new ship dimensions. Once the weight and displacement check, the program continues to estimate the vertical center of gravity.

Subroutine VCG makes this estimate. Centers are taken as fractions of the total depth of the ship to the main deck. The estimated KG is compared with the original estimate and a new estimate is made until there is agreement within one foot. KG location and metacentric height have both been checked by this point in the calculations so the test point on KG is set rather high to avoid overconstraining the problem.

After the vertical center of gravity balance has been made, the lead ship cost is estimated using a cost estimating procedure developed from "Flanagan's Method"(11) with modifications for the additional cost factor for aluminum construction and the additional machinery types of the model. This is accomplished by Subroutine COST which returns a cost breakdown by weight groups and additional costs for miscellaneous items as well as the total cost.

Finally, Subroutine OUTPUT is called. This routine takes all the values which have been calculated in the program as input and prints out the input data and the output of the feasibility study. After the output record is produced the program returns to MAIN and searches for more input data sets, reads the data and starts execution of the new case. This concludes a general description of the operation of the program.

The next chapter will present a more detailed description of the program and can be skipped without loss of too much continuity by a user not interested in how the program works. Because the SWATH is an unusual configuration, however, the naval engineer may find the background and derivation of the estimating relationships interesting.

CHAPTER VI
DESCRIPTION OF THE PROGRAM

6.1 Introduction

This chapter consists of thirteen parts, this introductory section and twelve sections describing in detail the derivation and use of various estimating relationships in the program. In this introductory section, the data base will be discussed and the organization of each of the following sections will be outlined.

The data from which this model was developed is from two major sources (8) and (11) which give the results of considerable ship synthesis using a Navy SWATH model and the Coast Guard Cutter Model, respectively. The Navy SWATH data was used for formulating estimating relationships peculiar to the SWATH and the Cutter Model was used for validation of other data against present Coast Guard practices and incorporation into the model where there was either good correlation or a good reason to accept Coast Guard estimates over Navy relationships, for instance in the deck area requirements for living spaces. There are also several other sources of SWATH data which were consulted in creating the data base for this model (3, 5, 14, 15, 16, 17, 18, 19, 20, 21). Table II gives a tabulation of the principal dimensions, operational specifications, optional features, weight estimates and several ratios used in developing the relationships of this model. The primary reference source for each ships' data is also listed in the table. These data were used for developing SWATH relationships. Throughout the remainder of this chapter graphs will be displayed which have been

plotted to reduce these data into simple, often linear curves. Other graphs in this chapter are taken from Goodwin[11] and show current Coast Guard designs and SWATH designs superimposed to test the applicability of these relationships to the SWATH design. If the data appear to fit well, Goodwin's relationships are used; if the data trends are the same but displaced, Goodwin's curves are modified to fit the data better.

The general organization of the sections on the individual subroutines will be similar. The subroutines will be described in the order in which they are called in the program. First the general purpose and approach for each subroutine will be defined. Then the required inputs will be listed. The majority of each section is devoted to the development of estimating relationships. The sources of the data, appropriate curves and the rationale of the development will be discussed. The important tests which the program must make to direct it in the proper execution of the solution will also be noted. However, each computer statement will not be described in order. It is assumed here that the reader has a basic knowledge of the FORTRAN computer language and can fill in the steps which are not described. The complete program listing is available in Appendix B for reference while reading these sections. A computer flow diagram of each subroutine is included along with the description of the program's relationships. Finally, the subroutine description will include an output list and a nomenclature list. The nomenclature list applies only to the subroutine under discussion in that section as similar variable names may be assigned to different variables in other parts of the program.

TABLE II

DATA BASE FOR SWATH MODEL DEVELOPMENT

FACTOR \ SHIP	1	2	3	4	5	6	7	8	9
Length	282	300	300	308	308	300	308	308	300
Displacement	5250	5560	5580	5720	5640	5580	5720	5640	4650
Hull Diameter	18.5	19.1	19.1	19.0	19.0	19.1	13.0	19.0	17.4
Draft	32.3	33.5	33.5	33.2	33.3	33.5	33.2	33.2	30.4
Speed									
Endurance									
Number Struts	1	1	1	2	2	1	2	2	1
Strut Length	180	180	200	80/90	80/90	200	80/90	80/90	180
Strut Beam	8.7	8.7	9.8	9.8	9.8	8.7	9.8	9.8	8.7
C_{WP}	.941	.941	.909	.860	.860	.909	.860	.860	.941
Box Length	214	214	214	252	234	214	252	234	214
Box Beam	90	96	96	96	96	96	96	96	96
Box Depth	23	23	23	14	23	23	14	23	23
Hull Separation									
Air Gap	15	15	15	15	15	15	15	15	15
Horsepower									
Machinery	GT	GT	GT	GT	GT	GT	GT	GT	GT
Material	Steel	Steel	Steel	Steel	Steel	Alum	Alum	Alum	Alum
Decks	2	2	2	1	2	2	1	2	2
GM_T	3.4	5.7	9.3	3.2	6.4	10.3	4.2	7.4	9.5
GM_L	16.2	13.2	24.2	83.9	73.5	75.2	84.9	74.5	13.8
Group 1 Weight	1918	1922	1942	2092	2022	1343	1312	1364	1310
Group 2 Weight	393	393	393	366	366	393	366	366	393
Group 3 Weight	176	176	176	176	176	176	176	176	176
Group 4 Weight	191	191	191	191	191	191	191	191	191
Group 5 Weight	420	420	420	420	420	420	420	420	420
Group 6 Weight	294	294	294	294	294	294	294	294	294
Group 7 Weight	76	76	76	76	76	76	76	76	76

TABLE II (Continued)

DATA BASE FOR SWATH MODEL DEVELOPMENT

FACTOR \ SHIP	1	2	3	4	5	6	7	8	9
Hull Volume	679464	731073	737427	597015	775286	737427	597015	775286	697709
Density Structure	7.27	6.77	6.78	9.03	6.72	4.69	5.66	4.53	4.84
WTl/Displ.	.42	.40	.40	.42	.41	.28	.26	.27	.32
Length/Diam.	15.2	15.7	15.7	16.2	16.2	15.7	16.2	16.2	17.2
Strut Length/Length	.64	.60	.67	.57	.57	.67	.57	.57	.60
Strut Beam/Diam.	.47	.44	.46	.52	.52	.46	.52	.52	.50
Draft/Diam	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Ship Type	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.	Med. ESC.
Reference	8	8	8	8	8	8	8	8	8

NOTES:

1) Dimensions in feet. Weights in tons. Speed in knots. Endurance in nautical miles.

2) C_{WP} = waterplane coefficient of strut
GM_T = transverse metacentric height
GM_L = longitudinal metacentric height

3) Machinery Types: GT = gas turbine
GT-E = gas turbine-electric
D-E = diesel-electric

4) Material Types: Steel = steel
Alum = aluminum

5) Ship Types:
Med. ESC. = Medium Escort (5000 tons)
SM. ESC. = Small Escort (2000 tons)

5) Ship Types (Continued)
PMR = Patrol Vessel
SSP = Semi Submerged Platform (190 tons)
AGOR = 240 foot AGOR SWATH
CUTTER = 240 foot USCG Cutter SWATH design
SSV72 = 1972 SWATH Supply Vessel design
SSV75 = 1975 SWATH Supply Vessel = design
SSSV75 = 1975 Semi Submerged Supply Vessel design
MCM = SWATH Mine Countermeasures Ship

TABLE II (Continued)

DATA BASE FOR SWATH MODEL DEVELCPMENT

FACTOR \ SHIP	10	11	12	13	14	15	16	17	18	19
Length	305	303	350	194	216	295	238	238	238	238
Displacement	4610	5630	5680	2060	2040	2250	2090	2110	2135	2370
Hull Diameter	17.4	19.1	17.8	13.9	14.0	12.0	13.0	13.2	13.2	13.8
Draft	30.4	33.6	31.2	23.9	24.4	21.0	22.7	23.1	22.7	24.0
Speed										
Endurance										
Number Struts	2	1	1	1	2	2	1	1	1	1
Strut Length	80/90	200	250	156	52/52	67/67	182	182	182	182
Strut Beam	8.7	8.7	6.0	6.5	6.5	5.0	5.0	5.0	5.0	6.0
C_{WP}	.876	.909	.903	.869	.788	.909	.811	.811	.811	.842
Box Length	252	214	214	136	136	272	162	162	162	162
Box Beam	96	96	96	94	94	94	80	80	80	80
Box Depth	14	23	23	23	23	14	23	23	23	23
Hull Separation										
Air Gap	15	15	15	15	15	15	15	15	15	15
Horsepower										
Machinery	GT	GT	GT	GT	GT	GT	GT	GT	GT	GT
Material	Alum	Steel	Steel	Alum	Alum	Alum	Alum	Alum	Alum	Alum
Decks	1	2	2	2	2	1	2	2	2	2
GM_T	3.4	9.2	5.7	23.8	3.3	2.4	4.0	4.0	4.0	4.5
GM_L	24.1	24.1	48.2	17.0	18.1	110.6	20.7	20.7	20.7	23.1
Group 1 Weight	1302	1953	2027	631	613	796	657	657	663	692
Group 2 Weight	366	393	360	267	267	267	267	267	267	267
Group 3 Weight	176	176	176	125	125	125	125	125	125	125
Group 4 Weight	191	191	191	87	87	87	87	90	90	87
Group 5 Weight	420	420	420	147	147	147	147	147	147	259
Group 6 Weight	294	294	294	76	76	76	76	76	76	172
Group 7 Weight	76	76	76	26	26	26	26	34	34	26

TABLE II (Continued)

DATA BASE FOR SWATH MODEL DEVELOPMENT

FACTOR \ SHIP	10	11	12	13	14	15	16	17	18	19
Hull Volume	556292	739462	723640	396968	387593	453912	397719	399973	399382	416720
Density Structure	6.03	6.80	7.22	4.09	4.07	4.52	4.26	4.23	4.28	4.28
WT1/Displ.	.32	.40	.41	.35	.35	.41	.36	.36	.36	.34
Length/Diam.	17.5	15.9	19.7	14.0	15.4	24.6	18.3	18.3	18.3	17.25
Strut Length/ Length	.56	.66	.71	.80	.48	.45	.77	.77	.77	.77
Strut Beam/ Diam.	.50	.46	.34	.47	.46	.42	.39	.38	.38	.44
Draft/Diam.	1.75	1.76	1.75	1.72	1.74	1.75	1.75	1.75	1.72	1.74
Ship Type	MED. ESC.	MED. ESC.	MED. ESC.	SM. ESC.	SM. ESC.	SM. ESC.	SM. ESC.	SM. ESC.	SM. ESC.	SM. ESC.
Reference	8	8	8	8	8	8	8	8	8	8

TABLE II (Continued)

DATA BASE FOR SWATH MODEL DEVELOPMENT

FACTOR \ SHIP	20	21	22	23	24	25	26	27	28	29
Length	248	155	200	81.25	240	240	200	196	196.9	260
Displacement	2045	786	1286	190	3032	3059	2850	3150	2400	3441
Hull Diameter	15.0	9.5	11.1	6.5	15	15.82	16X21	16X22		15.83
Draft	26.3	16.7	19.4	15.25	26.25	27.7	35	35	20.7	27.7
Speed		15	20	25	13	18.6	14	12	14	25
Endurance		2000+	2000+				9000	9000	5400	
Number Struts	1	1	1	2	1	1	2	2	1	1
Strut Length	189	112	131	23/24	200	184	40/40	40/40		
Strut Beam	6.8	5.5	5.5	3.8/3.6	7.5	7.5	10	10		
C_{WP}	.856	.86								
Box Length	162	95	110	76.8	171	184	140	140		
Box Beam	80	54	59.2	45	82	85	105	105	68	
Box Depth	23	13	13	7.5	13	23	10	10		
Hull Separation										
Air Gap	15	12	12	6	20	15	46	46		
Horsepower		2800	10000	4200	4850	12880	6000	6000	7040	40000
Machinery	GT	D-E	GT-E	GT	DIESEL	D-E	DIESEL	DIESEL	DIESEL	GT
Material	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Decks	2	1	1	1	1	2	1	1	1	1
GM_T	4.2				11.56	4.01				
GM_L	26.7				46.35	20.2				
Group 1 Weight	1193	354	538	99	1130	1319				1188
Group 2 Weight	267	100	280	13	213	380				300
Group 3 Weight	125	11	11	3	74	105				53
Group 4 Weight	87	3	4	1	19	90				37
Group 5 Weight	259	80	100	30	417	283				380
Group 6 Weight	172	27	50	1	234	201				230
Group 7 Weight	26	0	0	0	1	17				5

TABLE II (Concluded)

DATA BASE FOR SWATH MODEL DEVELOPMENT

FACTOR \ SHIP	20	21	22	23	24	25	26	27	28	29
Hull Volume	443597	104690	144650	35724	347734	486256				
Density Structure	6.93	8.71	9.59	6.21	8.37	6.99				
WT1/Displ.	.47	.52	.48	.52	.43	.55				.40
Length/Diam.	16.53	16.3	18.0	10.8	16	15.17	12.5/9.5	12.25/8.9		16.43
Strut Length/ Length	.76	.72	.66	.58	.83	.77	.4	.4		
Strut Beam/ Diam.	.45	.53	.50	.57	.50	.47	.48	.46		
Draft/Diam.	1.75	1.76	1.75	2.35	1.75	1.75	2.19	2.19		1.75
Ship Type	SM. ESC.	PMR	PMR	SSP	AGOR	CUTTER	SSV72	SSV75	SSSV75	MCM
Reference	8	14	14	14	14	10	16	21	21	3

The program accumulates, stores and transfers values of variables by using labeled common statements. This is done because a great number of variables are required to define a solution case and because it saves on computer storage space. Thus, in the input and output lists for each subroutine a code indicating the transfer and storage of a variable in labeled common is given in the form LC(AA) to indicate storage in labeled common AA and the code SCDA is used to indicate a subroutine call dummy argument.

6.2 MAIN Program

6.2.1 Purpose and Approach

The MAIN program performs the functions of reading all the input data, summation and bookkeeping for payload items which have been input, making initial estimates of the displacement, vertical center of gravity location and cubic number as functions of the input values and calling the XECUTE subroutine which controls the execution of each design case. The XECUTE subroutine is described in the next section. After XECUTE has completed the analysis of a design case control is returned to MAIN. MAIN then checks for more input data and reads the data for another run or, on finding no more data, directs the computer to stop.

6.2.2 Inputs Required

In this program there are only two variables which are assigned values at the beginning of the MAIN program; all other variables are either read into the program from the data cards or are assigned values in the routines. The two exceptions to the rule noted above are the variables IREAD and IWRITE which are merely dummy variables for the device numbers of the card reader and the printer. Dummy variables

were used here to simplify conversion of this program for use on different computers. The values assigned in the program as listed in the Appendix are for use on the IBM 370 computer with FORTRAN IV G1 or WATFIV compilers. The inputs read from cards will be described in the next paragraph.

6.2.3 Program Development

The format of the input data deck is listed in the User's Guide, Appendix A. The first input card of the input deck is used as a control to signal the computer that there is more data to follow or that there is no more data and the run should terminate. An INDEX value of 0 causes termination. The second input which is read is a heading which may contain any descriptive information about the computer run. This heading will be printed for all outputs using the data set which follows. The next input is a counter which determines the number of Armament, Ammunition and Cargo descriptive cards which follow. A maximum of 20 of this type of input data cards is specified. The group of cards which follows this counter is the armament, ammunition and cargo payload data. It may be arranged in any way and items may be grouped on one card or separated. However, for each card with a weight entry, a vertical center of gravity entry must follow as the next entry on the same card; these entries should be expressed as a ratio of the depth to the main deck. Required areas in the hull and deckhouse for these payload items may be entered; if an area is not specifically required in the deckhouse, it should be entered as a hull area. The materials cost for the payload items should also be entered in thousands of dollars at the time of construction of the ship. The next input is another counter which is used to

count the number of electronics input cards which follow. Again the maximum value of electronics cards is 20. The electronics input card is similar to the armament card in that it contains descriptive data, weight, center of gravity, required area and cost data. Manning input data are read next. This program requires manning data as an input. Then cost indices for use in the COST subroutine are input. These consist of the estimated labor rate during ship construction and inflation indices for computing material costs. The ninth input required is a description of the mission including the endurance days for provisions, the weight and the center of gravity position of the aircraft fuel. Then an input indicating whether the program is to compute the maximum speed for an input value of horsepower (JOPT=2) or the horsepower required to attain a specified speed (JOPT=1) is given. If JOPT=1 is specified the next data card read includes the sustained speed, endurance speed, endurance range and propulsive coefficient data. For JOPT=2, the next card includes the installed horsepower, specific fuel consumption values, endurance speed and range, propulsion auxiliaries electrical load, weight of lubricating oil, dimensions of the machinery spaces required, and the acquisition cost. The twelfth type of data card allows various options to be selected. Four machinery types are provided as options: MTYPE=1 is diesel, MTYPE=2 is diesel-electric, MTYPE=3 is gas turbine and MTYPE=4 is gas turbine-electric. A value of MTYPE=0 will cause the computer to assume that the next input value is INDEX; this feature can be used to stop the program. The results of a MTYPE specification other than 0-4 are unpredictable. The second option is for hull material; MOPT=1 is a steel hull with aluminum deckhouse, MOPT=2

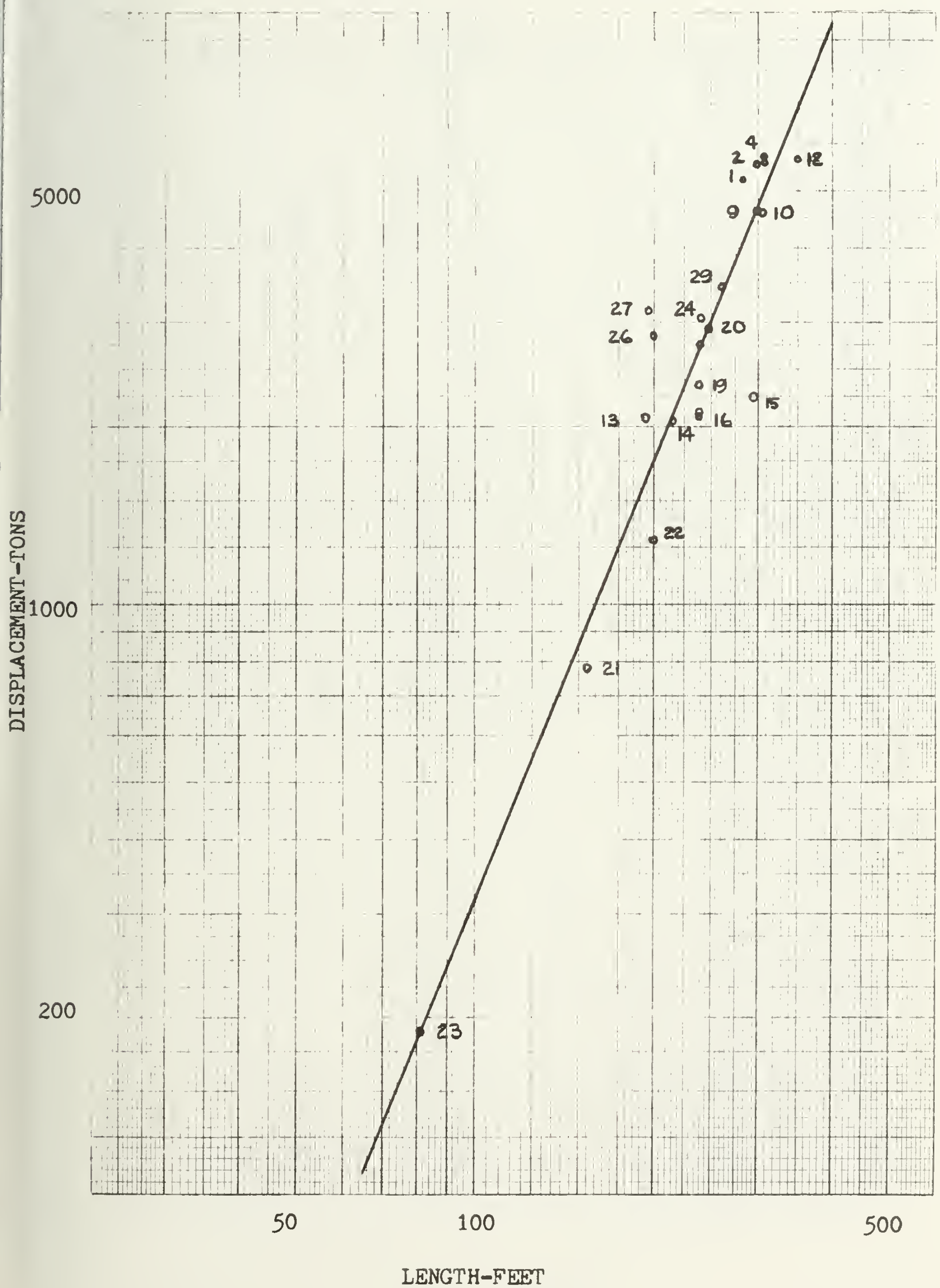
is for an all aluminum ship. The third option is a free surface correction term which can be used to influence the value of KG. The primary variable which can be varied in this option card is the ship length. The last option is for design and builders margin. Several option cards may be stacked together in an input deck; the program will interpret each as a new input case with the same payload description. A card with a MTYPE=0 entry is required to get to an entirely new data set. That completes the reading in of data.

MAIN also makes three starting estimates: displacement, vertical center of gravity and cubic number. Two approaches were applied to determining the estimating relationship for displacement. First, a mean design SWATH was hypothesized and its displacement calculated over a range of size. This equation was DPTRY=.00015707*LEN*LEN*LEN. Comparison with the SWATH data shown in Table II indicated that this equation estimated well in the midrange but was not very good on the ends. The second approach, a logarithmic plot and a mean line through all available SWATH data produced the second relationship, DPTRY= .004606265*LEN**2.427, which was used. See Figure 3. From limited vertical center of gravity data it appeared that KG/D did not vary widely and that it increased with length. Thus a mean line was drawn through the available data and the equation below was determined. See Figure 4.

KGTRY=LEN/(.0036786*LEN+5.5368)

During the study of the hypothetical mean SWATH mentioned above, a relationship was derived for total enclosed volume of the hull as a function of length and number of decks in the box. Since the first use of the cubic

FIGURE 3: TRIAL DISPLACEMENT VERSUS LENGTH



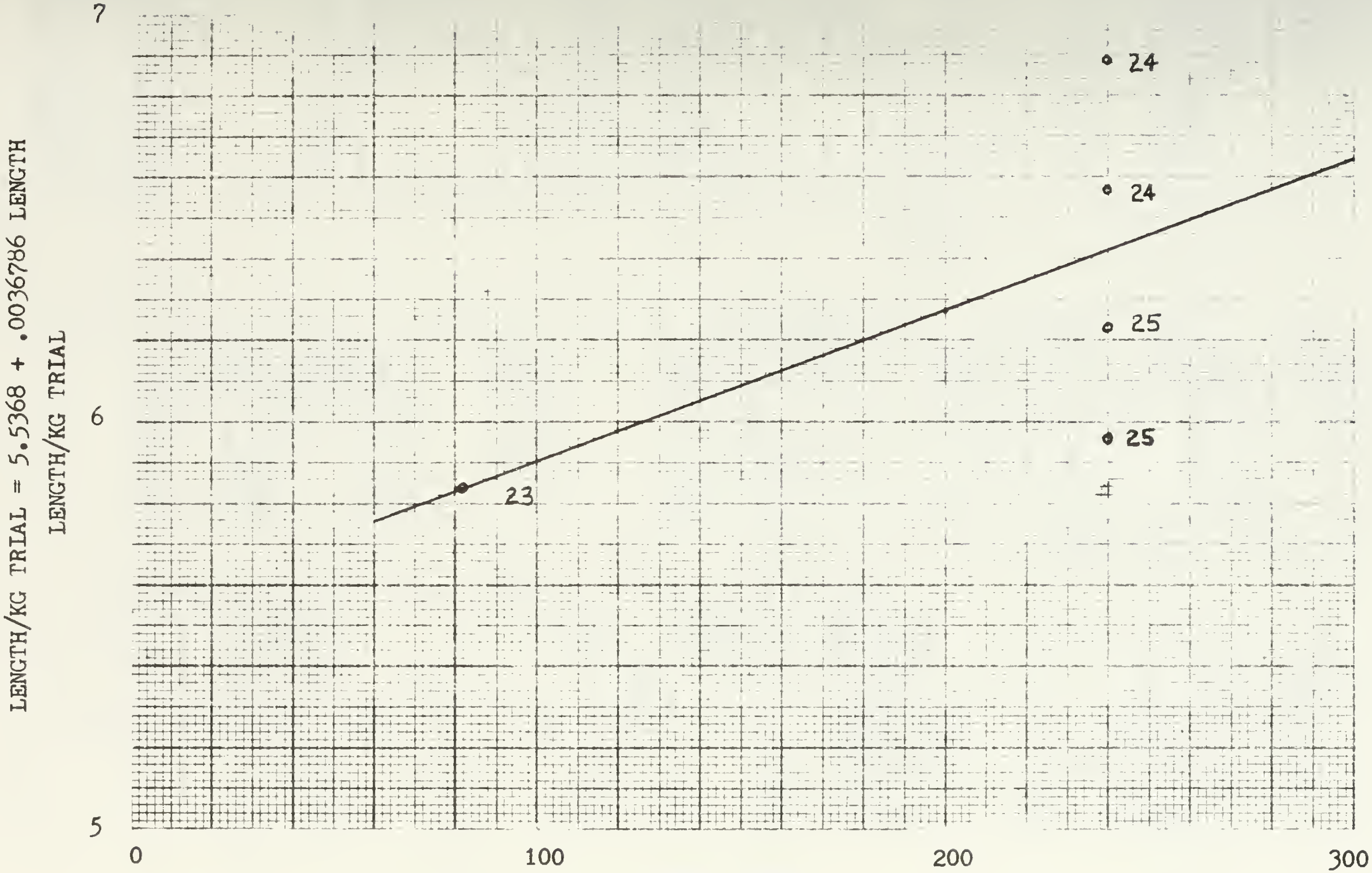
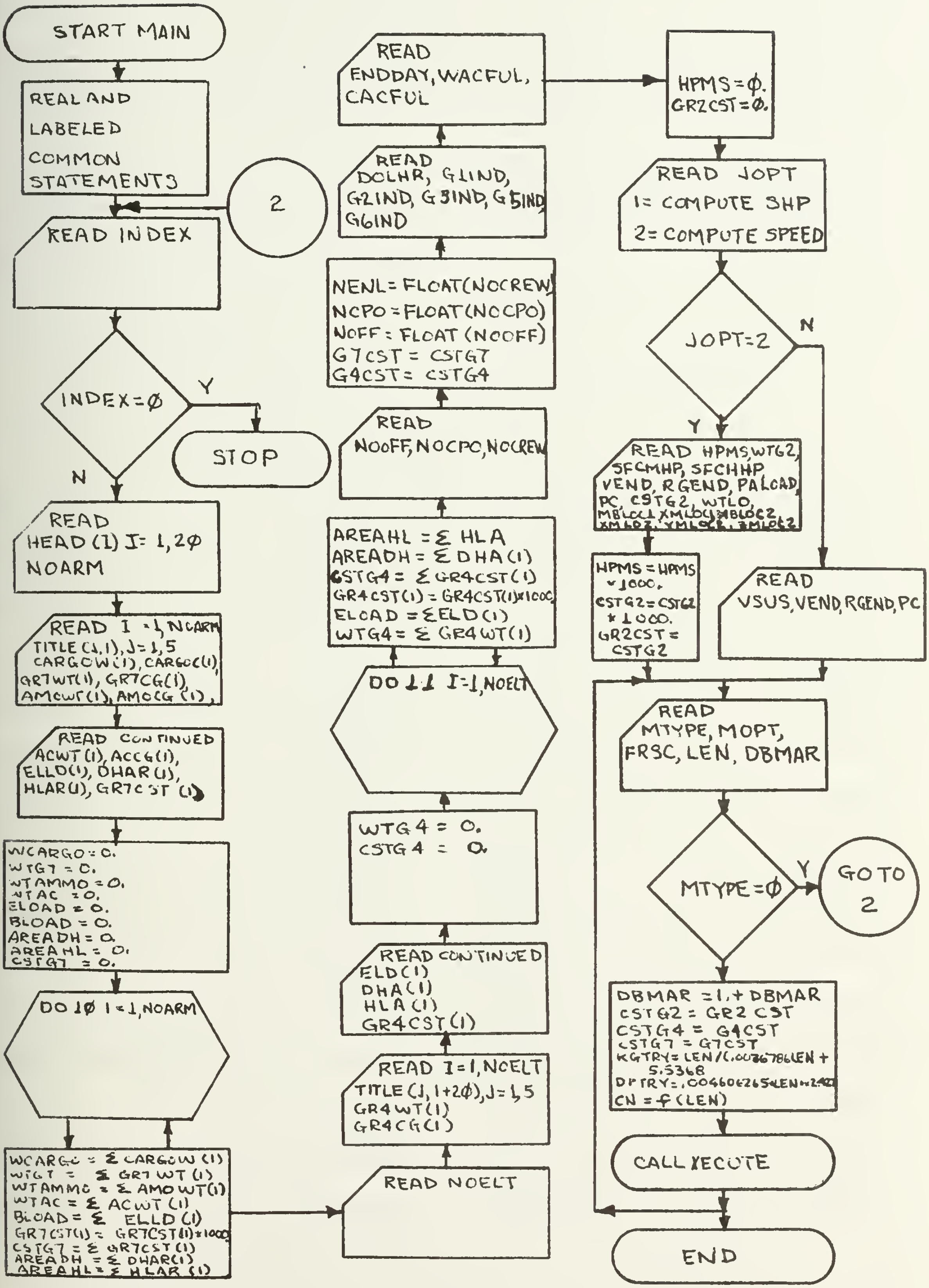


FIGURE 4: LENGTH/KG TRIAL VERSUS LENGTH

FIGURE 5: MAIN SUBROUTINE FLOW CHART



number is in electric plant sizing, it was felt that this relationship was sufficiently accurate and was used.

```
CN=165.048*LEN+6.196155*LEN*LEN+.005973*LEN*LEN*LEN
```

After making these estimates control of the program is passed to XECUTE. Only after a case has been calculated is control passed back to MAIN for more data reading.

6.2.4 Flow Chart

A flow chart for the MAIN program is shown in Figure 5.

6.2.5 List of Outputs of MAIN Program

ACCG (20)	LC(EE)	DHA(20)	LC(KK)
ACWT(20)	LC(EE)	DHAR(20)	LC(KK)
AMOCG(20)	LC(EE)	DOLHR	LC(NN)
AMOWT(20)	LC(EE)	DPTRY	LC(GG)
AREADH	LC(BB)	ELD(20)	LC(KK)
AREAHL	LC(BB)	ELLD(20)	LC(KK)
BLOAD	LC(DD)	ELOAD	LC(DD)
CACFUL	LC(HH)	ENDDAY	LC(AA)
CARGOC(20)	LC(EE)	FRSC	LC(GG)
CARGOW(20)	LC(EE)	G1IND	LC(NN)
CN	LC(BB)	G2IND	LC(NN)
CSTG2 (JOPT=2 only)	LC(MM)	G3IND	LC(NN)
CSTG4	LC(MM)	G5IND	LC(NN)
CSTG7	LC(MM)	G6IND	LC(NN)
DBMAR	LC(WW)	GR4CG(20)	LC(EE)

List of Outputs of MAIN Program (Continued)

GR4CST(20)	LC(KK)	NOFF	LC(AA)
GR4WT(20)	LC(EE)	PALOAD (JOPT=2 only)	LC(DD)
GR7CG(20)	LC(EE)	PC	LC(CC)
GR7CST(20)	LC(KK)	RGEND	LC(CC)
GR7WT(20)	LC(EE)	SFCHHP (JOPT=2 only)	LC(CC)
HEAD(20)	LC(FF)	SFCMHP (JOPT=2 only)	LC(CC)
HLA(20)	LC(KK)	TITLE (5,40)	LC(FF)
HLAR(20)	LC(KK)	VEND	LC(CC)
HPMS	SCDA	VSUS (JOPT=1 only)	LC(CC)
JOPT	LC(CC)	WACFUL	LC(LL)
KGTRY	LC(GG)	WCARGO	LC(LL)
LEN	LC(BB)	WTAC	LC(LL)
MOPT	LC(CC)	WTAMMO	LC(LL)
MTYPE	LC(CC)	WTG2 (JOPT=2 only)	LC(WW)
NCPO	LC(AA)	WTG4	LC(WW)
NENL	LC(AA)	WTG7	LC(WW)
NOARM	LC(FF)	WTLO (JOPT=2 only)	LC(LL)
NOELT	LC(FF)		

6.2.6 Nomenclature List

ACCG(20	aircraft vcg/DT, DT = depth to top of box
ACWT(20)	aircraft weight, tons
AG	air gap clearance under box, feet
AKNOT(12)	speed curve values
AMOCG(20)	ammunition vcg/DT

Nomenclature List (Continued)

AMOWT(20)	ammunition weight, tons
AREADH	total input deckhouse arrangements area, sq ft
AREAHL	total input hull arrangements area, sq ft
AVGKW	average electrical load, KW
BBOX	beam of box, feet
BS	beam of strut, feet
BLOAD	total armament electrical load, KW
CACFUL	aircraft fuel vcg/DT
CARGOC(20)	cargo vcg/DT
CARGOW(20)	cargo weight, tons
CCARGO	total vcg of cargo inputs, feet
CCST	construction services cost, dollars
CGAC	total vcg of aircraft, feet
CGAMMO	total vcg of ammunition, feet
CGCREW	total vcg of crew, feet
CGFUEL	total vcg of ships fuel, feet
CGLO	total vcg of lub oil, feet
CGPE	total vcg of personnel effects, feet
CGPS	total vcg of personnel stores, feet
CN	cubic number, cubic feet
CSTG1	total cost of weight group 1, dollars
CSTG2	total cost of weight group 2, dollars
CSTG3	total cost of weight group 3, dollars
CSTG4	total cost of weight group 4, dollars
CSTG5	total cost of weight group 5, dollars
CSTG6	total cost of weight group 6, dollars

Nomenclature List (Continued)

CSTG7	total cost of weight group 7, dollars
CWP	waterplane coefficient
DB	depth of box, feet
DBMAR	design and builders margin
DCST	design cost, dollars
DH	diameter of hulls, feet
DHA(20)	electronics deckhouse area, sq ft
DHAR(20)	armament deckhouse area, sq ft
DHV	deckhouse volume, cu ft
DOLHR	labor rate, dollars/hour
DPTRY	displacement estimate, tons
DT	depth of ship to top of box, feet
ELD(20)	electronics electrical load, KW
ELKW	generator rated load, KW
ELLD(20)	armament electrical load, KW
ELOAD	total electronics electrical load, KW
ENCVOL	total volume of hull and deckhouse, cu ft
ENDDAY	number of endurance days for dry provisions
FRSC	free surface correction, feet
G1IND	cost index for weight group 1
G2IND	cost index for weight group 2
G3IND	cost index for weight group 3
G4CST	total material cost weight group 4, dollars
G5IND	cost index for weight group 5
G6IND	cost index for weight group 6

Nomenclature List (Continued)

G7CST	total material cost weight group 7, dollars
GR2CST	total material cost weight group 2, dollars
GR4CG(20)	group 4 vcg/DT
GR4CST(20)	material cost weight group 4, dollars
GR4WT(20)	group 4 weight, tons
GR7CG(20)	group 7 vcg/DT
GR7CST(20)	material cost weight group 7, dollars
GR7WT(20)	group 7 weight, tons
H	draft, feet
HEAD(20)	descriptive heading (alphanumeric)
HLA(20)	electronics hull area, sq ft
HLAR(20)	armament hull area, sq ft
HPMS	maximum sustained shaft horsepower
INDEX	control variable
IREAD	card reader dummy variable
IWRITE	line printer dummy variable
JOPT	input option variable for machinery
KGTRY	initial KG estimate, feet
LEN	length of torpedo-like hulls, feet
MCST	miscellaneous costs, dollars
MBLOC1	location of propulsion system index
MBLOC2	location of prime mover index
MOPT	material type option
MTYPE	machinery type option
NCPO	number of chief petty officers (real)
NENL	number of enlisted men (real)

Nomenclature List (Continued)

NOARM	number of armament input cards
NOELT	number of electronics input cards
NOFF	number of officers (real)
NOCPO	number of chief petty officers (integer)
NOCREW	number of enlisted men (integer)
NOOFF	number of officers (integer)
PALOAD	propulsion auxiliary electrical load, KW
PC	propulsive coefficient
RGEND	endurance range, nautical miles
SEP	separation of hull centerlines, feet
SFCHHP	specific fuel consumption at half horsepower, lbs/SHP-hr
SFCMHP	specific fuel consumption at maximum horsepower, lbs/SHP-hr
SHP(12)	shaft horsepower curve values
SHPE	shaft horsepower at endurance speed
SHPM	shaft horsepower at maximum speed
TITLE(5,40)	line titles (alphanumeric)
TOTCST	total lead ship cost, dollars
VEND	endurance speed, knots
VSUS	maximum sustained speed, knots
WACFUL	weight of aircraft fuel, tons
WCARGO	total cargo weight, tons
WFULLD	full load weight, tons
WLSHIP	light ship weight, tons
WTAC	total aircraft weight, tons

Nomenclature List (Continued)

WTAMMO	total ammunition weight, tons
WTCREW	total crew weight, tons
WTFUEL	total ships fuel weight, tons
WTG1	total group 1 weight, tons
WTG2	total group 2 weight, tons
WTG3	total group 3 weight, tons
WTG4	total group 4 weight, tons
WTG5	total group 5 weight, tons
WTG6	total group 6 weight, tons
WTG7	total group 7 weight, tons
WTLO	weight of lub oil, tons
WTPE	weight of personal effects, tons
WTPS	weight of personnel stores, tons
XF	longitudinal distance from stern to center of strut, feet
XLB	length of box, feet
XLS	length of strut, feet
XMLOC1	length of propulsor space, feet
XMLOC2	length of prime mover space, feet
YMLOC1	width of propulsor space, feet
YMLOC2	width of prime mover space, feet
ZMLOC1	height of propulsor space, feet
ZMLOC2	height of propulsor space, feet

6.3 Subroutine XECUTE

6.3.1 Purpose and Approach

Subroutine XECUTE controls the execution of each trial case input to the program. All of the program subroutines are called by this routine. XECUTE also generates a number of error messages. When the constraints of the data base are violated, when improper data is input, when a set of infeasible requirements or when no balance between assumed and calculated variables can be attained within a reasonable number of iterations, the subroutine calls for an output printing routine which prints the input data and the type of error which has been detected. If assumptions have been made to approximate a solution, a warning message is also printed along with the solution.

XECUTE calls up each of the subroutines listed in Figure 2 in order. The ship's dimensions are determined, the required horsepower calculated, liquids and electrical plant requirements determined, a volume balance is made and then a weight estimate is completed. Then XECUTE controls an iterative procedure to bring the weight estimate and displacement into agreement. After the weight-displacement check is made, another estimate and iteration procedure is used to balance the center of gravity location. After completing this balance, the routine directs the computation of the ship cost and, finally, printing of the answers.

6.3.2 Input List for Subroutine XECUTE

DPTRY	LC(CG)	JOPT	LC(CC)
HPMS (JOPT=2 only)	SCDA	KGTRY	LC(GG)

LEN . . . . LC(BB) VEND . . . . LC(CC)

MTYPE . . . . LC(CC) VSUS . . . . LC(CC)

6.3.3 Program Development

This subroutine follows the approach used by many ship synthesis models in making an iterative solution to the design problem, but there are two differences-the method used for determining horsepower and the control over machinery selection.

First the DIM subroutine is called to determine the ship dimensions. The calling argument (R) is used to transfer values of excess KG. If the DIM routine cannot determine a suitable set of dimensions which meet the input requirements, the length is set equal to -10 feet and the XECUTE routine, sensing an error, prints an error statement.

The next routine called HPCALC is the longest and most complicated in the entire program. It also requires a large percentage of the total computation time in the program. Some control over the total running time and costs of the program is provided by limiting the number of HPCALC iterations to 5 by the statement:

```
IF(JNDEX.GT.5.OR.KNDEX.GT.5) GO TO 99
```

It was found that about 5 iterations are required for the geometry and horsepower requirements to stabilize during iterations. Although this test reduces the cost of the program by eliminating the HPCALC routine from the iteration after it is assumed that the horsepower remains relatively constant, it introduces an error in the final calculations. The user of the program recieves a warning that this has occurred as part of the output.

HPCALC is a routine which calculates a set of points on a speed-power curve for the ship geometry which has been input. These values of speeds and horsepowers are stored in two arrays. SHP(12) and AKNOT(12). If any errors in the inputs to the HPCALC routine have occurred, an error message is generated.

Subroutine UGLYDK is called to pass a spline cubic fit to the set of data points generated by HPCALC. This routine was prepared by Kerwin and is in general use at MIT. It is considered to be part of the library for the program and will not be described in detail in this thesis. The arguments of the routine will be noted here, however.

CAL UGLYDK(10, 1, 1, AKNOT, SHP, ESL, ESR, AE)

The first argument is the number of input data points. The second and third are indicators for the method in which the ending slopes are treated by the routine: 1, 1 indicates that the end slopes are to be tangents between the last two points at either end. The fourth argument is the array of input x values. The array of input y values, SHP, is the fifth argument. ESL and ESR are the left and right end slopes measured in degrees and these arguments are ignored when the second and third arguments are 1, 1. AE is the one dimensional array of coefficients of the simultaneous equations solved to plot this curve. Subroutine UGLYDK calls Subroutine SIMQ, another Kerwin program considered as part of the library. This routine solves the system of simultaneous equations required to make up the spline cubic fit.

If the program is to calculate the horsepower required to sustain an input speed, Subroutine EVALDK is called next. This subroutine

is another of the Kerwin library routines. Its purpose is to evaluate the ordinate of a curve plotted by UGLYDK, given the abscissa value.

```
CALL EVALDK(10, 1, AKNOT, VSUS, SHPM, AE)
```

The first argument is the number of input data points; the second argument is the number of output values desired; the third argument is the x axis input value array; the fourth argument is the x axis value desired as an output; the fifth argument is the output y value, in this case the shaft horsepower; the last argument is the coefficient array generated by UGLYDK. The return from the call to EVALDK is the required value of horsepower. EVALDK is called for both the maximum sustained speed and endurance speed horsepower calculations. The maximum sustained speed is defined as the speed that can be made when the shaft horsepower is 80 percent of the maximum sustained horsepower. Therefore, the value returned for SHPM is divided by 0.8 and carried on to the rest of the program.

If the option to calculate the maximum speed for a given input shaft horsepower is exercised, two first approximations of speed are made, VMAX and VMAX1=0.95*VMAX, and EVALDK is applied to find the corresponding horsepowers. Then a modified Newton-Raphson iteration is carried out using as an approximation of the slope of the horsepower curve.

d(SHP)/d(AKNOT) at VMAX, DELHP=(SHP1-SHP2)/(VMAX-VMAX1).

The iteration stops when the difference between the two successive speed estimate values is less than one half percent of the best estimate. This method provides for relatively rapid convergence. The value of

endurance horsepower is computed using EVALDK in the same manner for this option as in the first.

The next section of the XECUTE routine determines whether the design trial case is still feasible with the machinery type specified and the geometry and horsepower requirements calculated. Diesel propulsion plants of more than 14000 shaft horsepower or in ships with hull diameters less than 14 feet are prohibited by this model. Diesel-electric and gas turbine-electric plants over 30000 shaft horsepower or with hulls too small to accept the propulsion motors are prohibited. Gas turbine propulsion is assumed to have the gas turbines mounted in the box for small horsepowers and in the hulls for large horsepowers. If the beam of the struts is too small for removal of the turbine components, this case must be prohibited. No plant above 70000 horsepower is permitted. If the machinery type selection, geometry and horsepower requirements are infeasible, an error message is printed out which suggests either specifying the machinery to be installed (JOPT=2) or gas turbine machinery. If the design trial case is still feasible, control is directed to the next subroutine.

Subroutine EPLANT is called to calculate the average electrical load and the size of the ship service generators.

Subroutine LIQ is called to calculate the weight of fuel, lubricating oil and potable water.

If the dimensions of the machinery space have been specified in the inputs using JOPT=2, subroutine MACHBX is not executed. If the machinery space size is not specified, MACHBX estimates the dimensions of the various machinery spaces.

Subroutine VOLUME is called next. This routine computes the required volumes and areas and balances the required and available areas. It adjusts the deckhouse size and the number of decks in the box to provide sufficient area. If insufficient area or volume is available, the value of LEN is set negative and an error message is generated by XECUTE.

Subroutine WEIGHT calculates all the weights which have not been input previously and determines the full load displacement. The returned value of full load displacement, WFULLD, and the displacement estimate, DPTRY, are used to generate the starting values for another Newton-Raphson iteration to determine the final displacement. The iteration is continued until the weight and displacement check within 9 tons or until the iteration has been completed 20 times. If the iteration is not converging an error message is generated.

Once the weight and displacement are sufficiently close, Subroutine VCG is called to calculate the vertical center of gravity location. An averaging procedure is used to make new estimates of the KG. The iteration proceeds until the difference in the estimate, KGTRY, and the returned value, CFULLD, is less than 1 foot. A limit of 20 iterations and an appropriate error message is provided. The wide value of the test is used because of the separation of the hulls controlling effect on stability. If excess stability occurs in the ship, it is still feasible but overdesigned. The program prints out a value of excess KG available.

After all balances have been completed, the cost of the ship is calculated by Subroutine COST.

Finally, the OUTPUT subroutine is called. A value of 1 in the second argument of the call prints the input data and an appropriate error message; a value of 2 causes both the input and output data to be printed. If an error message is generated, the program returns to MAIN for more input data.

6.3.4 Flow Chart

Figure 6 shows a flow chart for Subroutine XECUTE. Note the iteration for speed when JOPT=2 on the top of the second page of the figure, the decision on a feasible selection of machinery and dimensions at the bottom of the second page, the weight-displacement iteration on the bottom of the third page and the VCG iteration in the upper right quadrant of the third page.

6.3.5 Output List for Subroutine XECUTE

DPTRY. . . . . LC(GG)

EXCKG. . . . . SDCA

KGRTY. . . . . LC(GG)

SHPE. . . . . LC(CC)

SHPM . . . . LC(CC)

6.3.6 Nomenclature List

CFULLD	vertical center of gravity, KG, feet
DELHP	derivative of horsepower function
DP1	used to store DPTRY value, tons
EXCKG	excess KG, feet
FACTOR	derivative of weight function
JNDEX	vcg counter

FIGURE 6a: XECUTE SUBROUTINE FLOW CHART

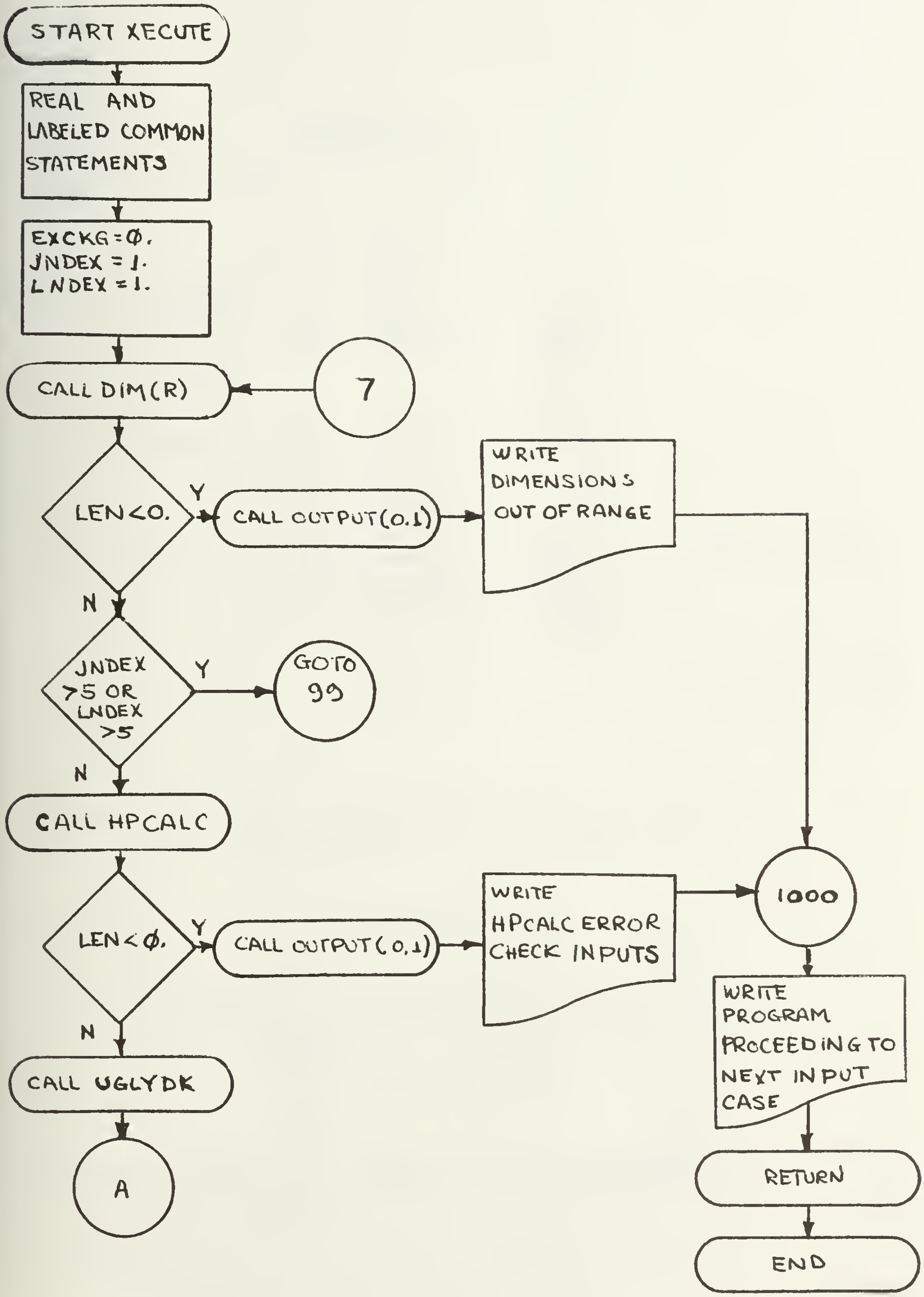


FIGURE 6b: XECUTE SUBROUTINE FLOW CHART-continued

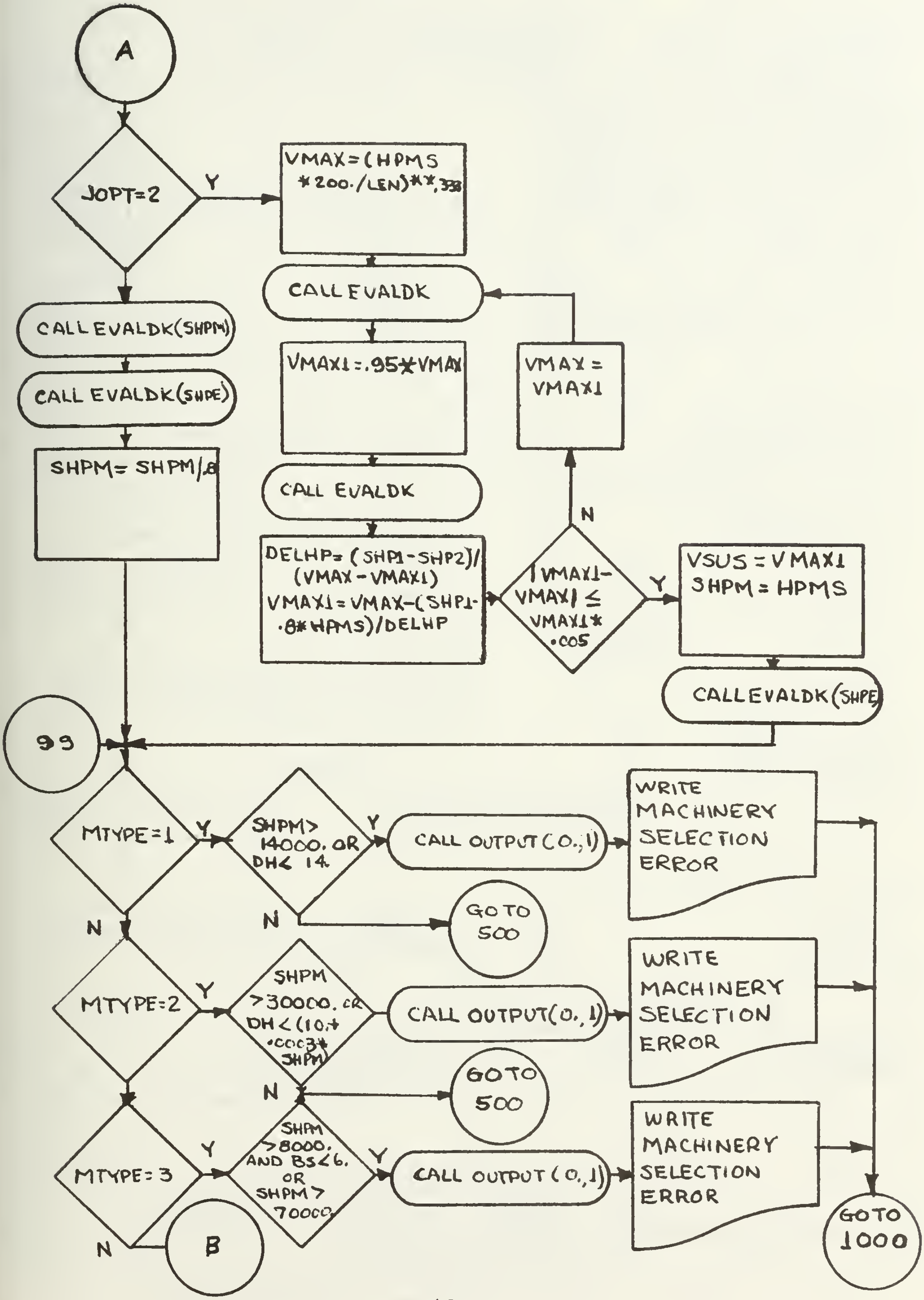
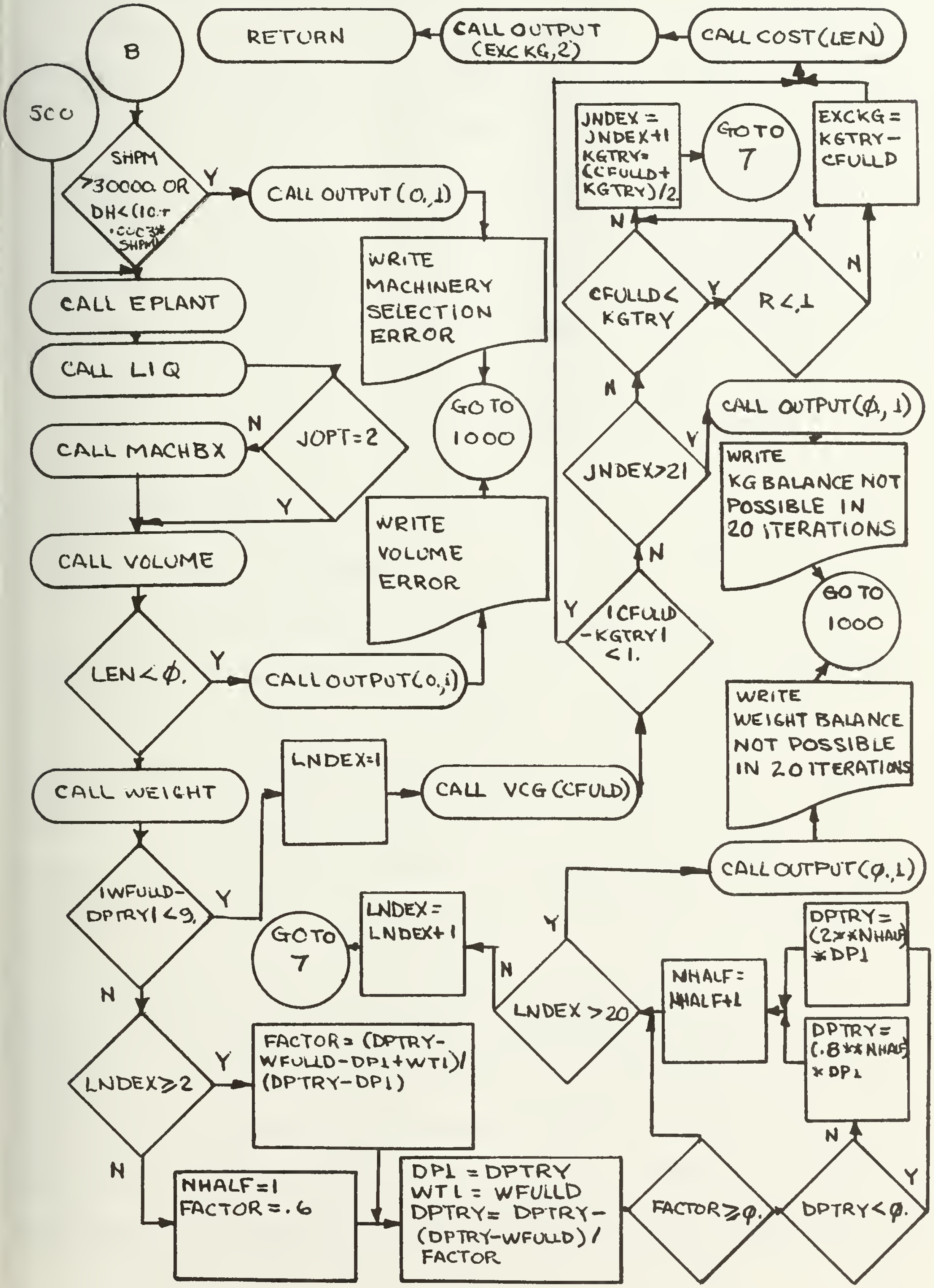


FIGURE 6c: XECUTE SUBROUTINE FLOW CHART-continued



Nomenclature List (Continued)

LNDEX	weight counter
NHALF	displacement trial counter
R	excess KG, feet
SHP	dummy used for shaft horsepower
SHP1	dummy used for shaft horsepower
SHP2	dummy used for shaft horsepower
VMAX	dummy used for speed, knots
VMAX1	dummy used for speed, knots
WT1	used to store WFULLD, tons

6.4 Subroutine DIM

6.4.1 Purpose and Approach

This routine determines the ship dimensions based on the input value of length and average SWATH geometry. The routine determines the diameter of the hulls, the strut length, strut width, waterplane coefficient and hull separation. The length, width, depth and air gap clearance of the box are also determined. Since the resistance determination made in Subroutine HPCALC requires the location of the strut on the hulls as an input, the DIM routine places the strut on the hull.

Several assumptions are necessary to prepare this subroutine. The hull is assumed to be of cylindrical form with an elliptical nose of length three times the diameter and a conical tail of length five times the diameter. Only one strut cases are allowed. This assumption was made considering two factors: the additional complexity involved in allowing more than one strut, and the results of several resistance

studies and preliminary design studies which indicate that in the service environment expected for vehicles designed by this model only single strut alternatives are desirable. The strut is sized with considerations for resistance and stability. Strut width is assumed to have the major impact on wave-making resistance and thus is increased slowly. The strut length is the primary variable assumed to influence longitudinal stability. The strut section is assumed to consist of parabolic nose and tail sections of lengths 3 and 5 times the strut beam, respectively, connected by a parallel mid section. The strut is wall-sided. Hull separation is assumed to be the primary variable influencing transverse stability. These simplifying assumptions result in rapid ship sizing. The box dimensions are assumed by this model to be 20 feet longer than the struts and of width equal to hull separation plus diameter. Air gaps are determined following SWATH design practice.

6.4.2 Input List for Subroutine DIM

DPTRY	LC(GG)	KGTRY	LC(GG)
FRSC	LC(GG)	LEN	LC(BB)

6.4.3 Program Development

This routine determines the diameter of the hulls, the volume of the hulls, checks for the displacement fraction of the hulls and then calculates a strut size which satisfies the stability requirements of the SWATH and attains a balance between the displacement of the ship and the assumed starting displacement. Then the box is sized and the strut location and air gap determined.

The diameter of the hulls is determined in two ways. Length/Diameter ratio versus length for ships in the data base are plotted in Figure 7. Using this relationship as a starting point, the diameter is determined. After the hull volume is calculated, the displacement of the hulls is required to be at least 65 percent of the trial displacement. If this test is not met, the hull diameter is incremented until the displacement of the hulls is at least 65 percent of the trial displacement. Length/Diameter ratio plotted versus speed-length ratio was investigated as an estimating method and found to give larger data scatter than the relation used.

Displacement balance and resistance considerations drive the calculation of strut dimensions. The strut size is incremented until the displacement checks. First the length of the strut is incremented until the ratio of strut length to hull length exceeds 0.80, a limit of good practice set in the model. Then the waterplane coefficient is incremented between values of 0.84 and 0.94. Only two ships in the data base fall outside these limits. To reduce the effect of hull dimensions on resistance, the beam of the strut is incremented last. The range of acceptable beams is from 4 feet, for structural and access considerations, to 55 percent of the hull diameter. There is only ship outside these limits in the data base; the SSP has a strut beam of 3.6 feet. If no displacement balance can be achieved within the limits of this increment loop, the program returns an error message.

After the displacement balances, longitudinal metacentric height is checked. A relation between waterplane coefficient and inertia coefficient for the assumed waterplane shape is plotted in Figure 8. An

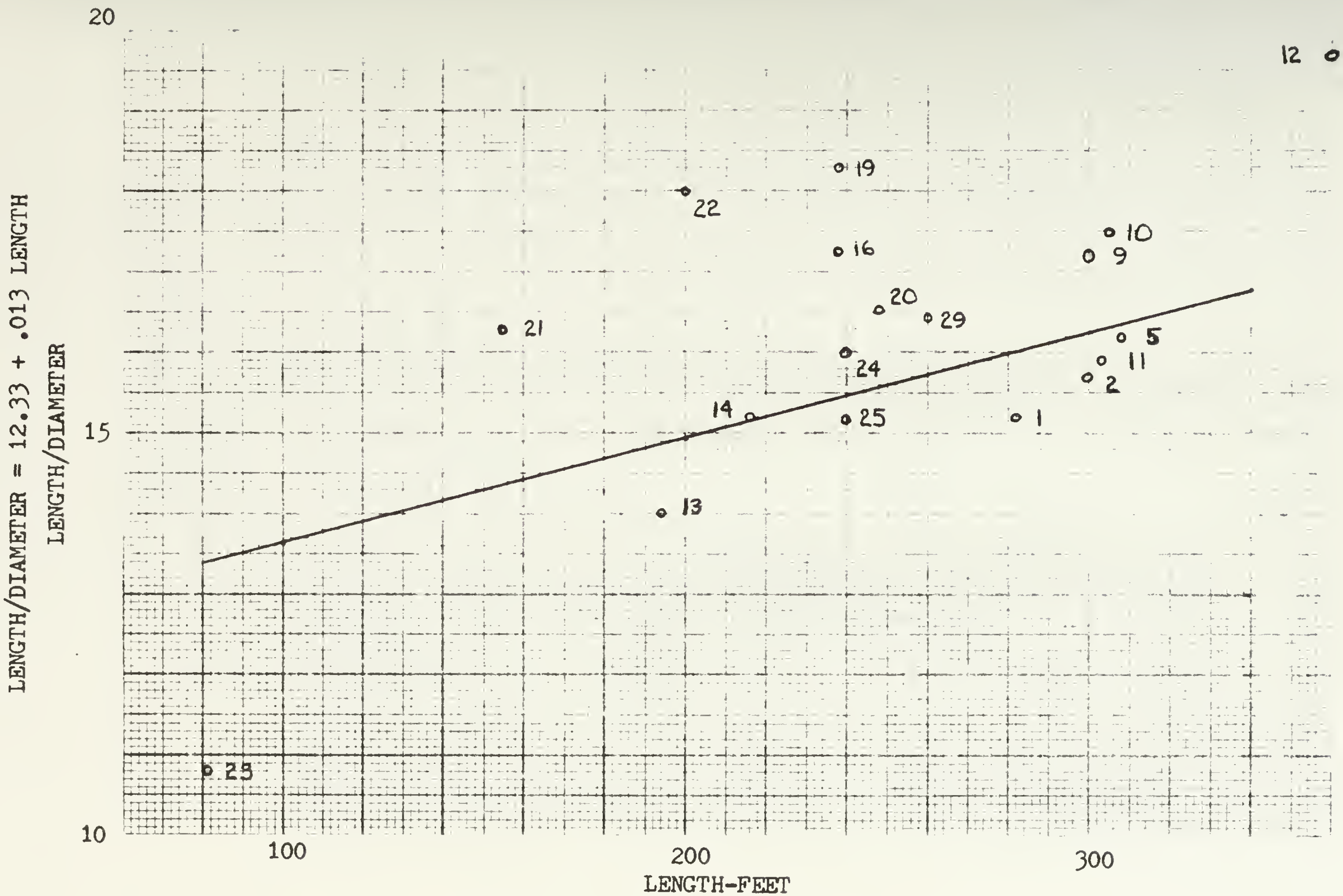
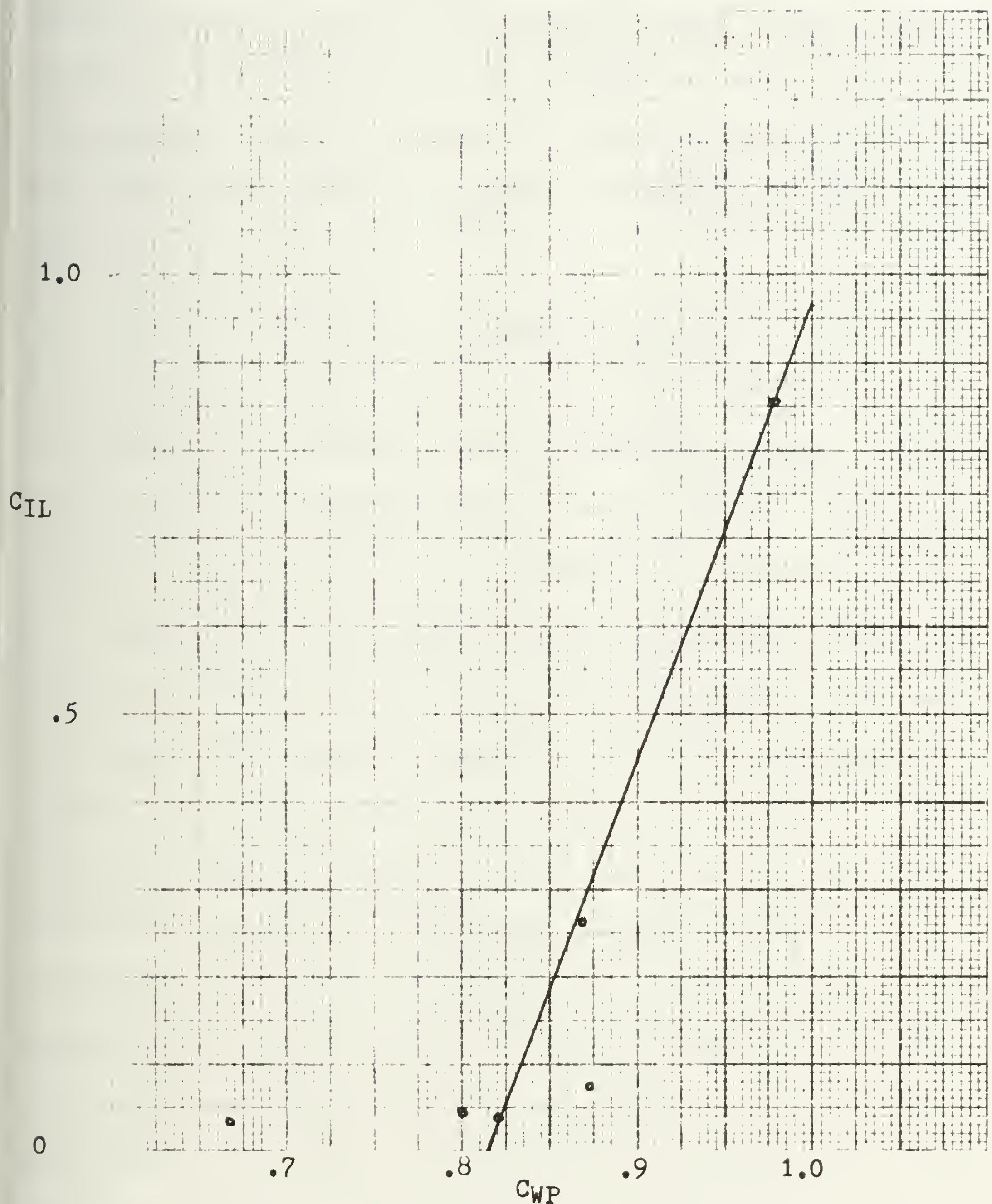


FIGURE 7: LENGTH/DIAMETER VERSUS LENGTH

FIGURE 8: C_{IL} VERSUS C_{WP}



$C_{IL} = I_L/(\text{STRUT LENGTH})^3 \times \text{STRUT WIDTH}$

$C_{IL} = 5.2141\ C_{WP} - 4.2491$

estimate is made of the center of buoyancy location. BG is calculated from the trial KG value. No allowance is made for free surface in the determination of longitudinal metacentric height, GML. A test value of 0.1 times the length of the strut is assumed in this routine. If the test is passed, the program continues to calculate the transverse metacentric height as a function of the separation. If the test is failed, the program returns an error.

Transverse metacentric height is estimated using a relation given in (5). Separation of the hulls is varied from .22 to .40 times the length of the hulls, until the test value for metacentric height, .2 times the hull diameter, .2*DH, is exceeded. If a separation of more than .4*LEN is required to meet this criterion, the program returns an error.

The final section of this subroutine calculates additional ship dimensions required in the remainder of the program. The value of excess KG, R, is computed using the same relationships previously applied. The strut is placed on the hull with its center at 52 percent of the hull length forward of the tail. This is an average value for existing SWATH designs. The box dimension relationships are representative of SWATH designs and are held fixed in this model. Minor variations in box size may make rather large changes in volume due to the box form. The depth of the box is initialized for a one deck ship. Air gap is determined as a function of length and is held constant at 15 feet for ships longer than 200 feet. This provides for reduced effects of wave slap and seaway leads up to sea state 5.

6.4.4 Flow Chart

Figure 9 shows a flow chart for Subroutine DIM.

6.4.5 Output List for Subroutine DIM

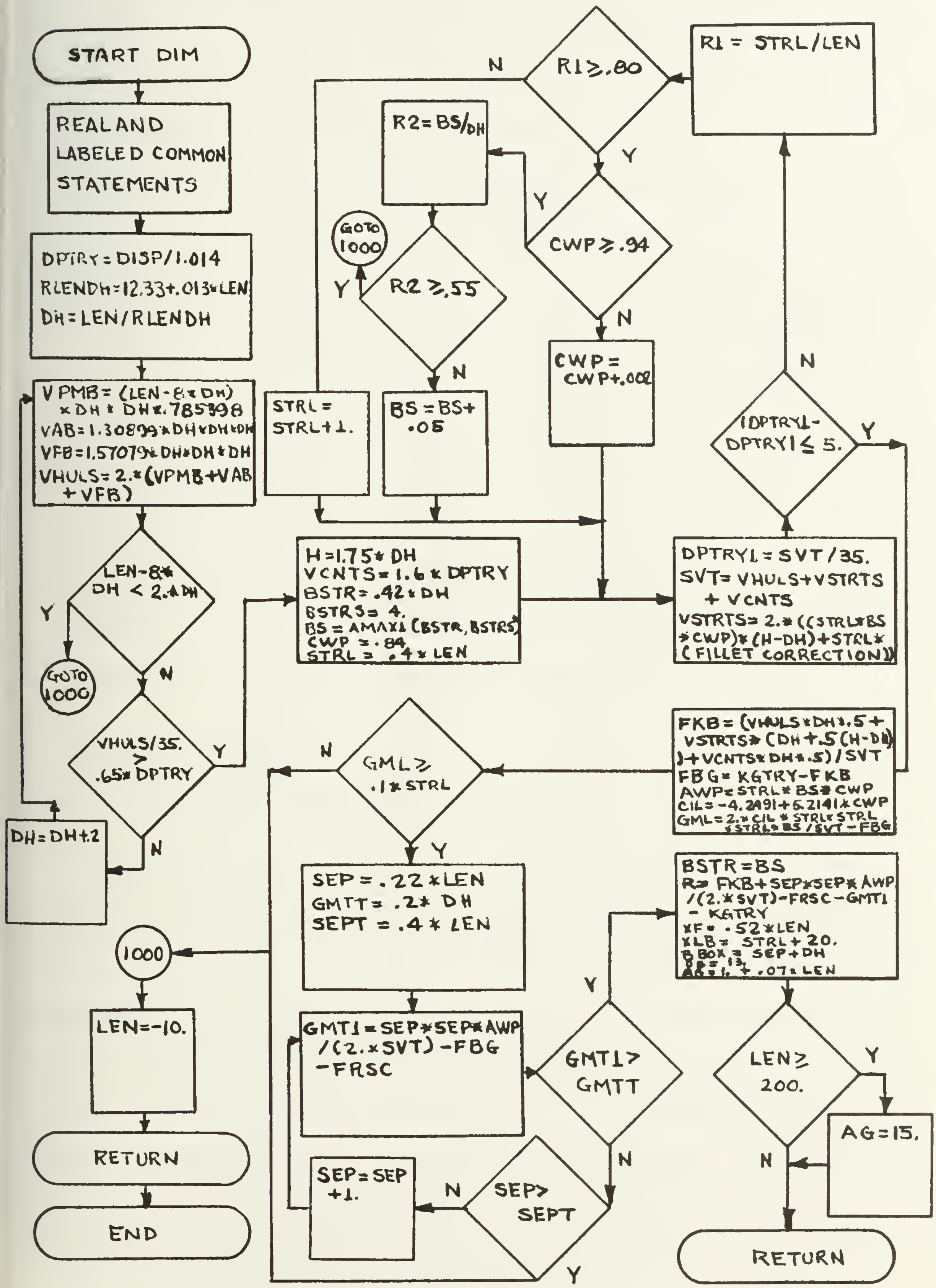
AG	LC(JJ)	H	LC(JJ)
BBOX	LC(GG)	R	SDCA
BS	LC(GG)	SEP	LC(JJ)
CWP	LC(GG)	XF	LC(JJ)
DB	LC(JJ)	XLB	LC(JJ)
DH	LC(GG)	XLS	LC(GG)

6.4.6 Nomenclature List

All variables used in this routine are the same as those defined for the MAIN program with the following exceptions:

AWP	area of the waterplane of one strut, sq ft
BSTR	beam of strut, ft-same as BS in MAIN
BSTRS	minimum beam of strut, ft
CIL	inertia coefficient of waterplane
DISP	displacement, tons - same as DPTRY in MAIN
DPTRY	displacement of moulded form, tons
FBG	distance from center of buoyancy to center of gravity, ft
FKB	distance from baseline to center of buoyancy, ft
GML	longitudinal metacentric height, ft
GMTT	test value for transverse metacentric height, ft

FIGURE 9: DIM SUBROUTINE FLOW CHART



Nomenclature List (Continued)

GMT1	transverse metacentric height, ft
R	excess KG, ft
RLENDH	Length-Diameter ratio
R1	strut length/hull length ratio
R2	strut base/hull diameter ratio
SEPT	test value for hull centerline separation, ft
STRL	strut length, ft-same as XLS in MAIN
SVT	total submerged volume, cu ft
VAB	volume of hull tail, cu ft
VCNTS	volume of control surface, cu ft
VFB	volume of hull nose, cu ft
VHULS	total volume of hulls, cu ft
VPMB	volume of parallel section of hull, cu ft
VSTRTS	volume of struts, cu ft

6.5 Subroutine HPCALC

6.5.1 Purpose and Approach

Subroutine HPCALC calculates points on a speed-power curve for the SWATH geometry input and it stores the values of speed and horsepower in two arrays which can be recalled and used to determine the horsepower requirements or speed attained for a given horsepower by an interpolation procedure in Subroutine XECUTE. This routine is based entirely on the work of Richard Chapman[12,22]. Chapman's SWATH resistance program, DRAG, is general in its application. It accepts varied geometries, speed increments, options on control surfaces,

hydrodynamic assumptions and includes several types of plotting routines. Chapman uses a combination of empirical drag coefficient formulations, standard frictional drag formulations, interference and eddy-making drag correction factors and a linearized potential flow solution for wave making drag. In this synthesis model, certain simplifications of this program were desirable to reduce the overall size of the program and expense of generating feasible solutions.

The simplifications of the DRAG program which were made for this subroutine restrict its use to the SWATH forms which are generated by this model. Two hull SWATH configurations with one strut per hull are assumed. The hulls are assumed to have elliptical noses of length 3 times the hull diameter and parabolic tails of length 5 times the hull diameter. The struts are assumed to have parabolic noses and tails of length 3 times the strut beam and 5 times the strut beam, respectively and a parallel section between the nose and tail. No appendages are assumed in the calculation although a 6 percent appendage resistance is added at the end of the calculation. The routine assumes a 10 percent eddy-making drag correction. A speed range of 6 to 33 knots with a 3 knot increment is assumed fixed in this routine. The interested reader is referred to reference (12) for a discussion of the theory of the DRAG program.

6.5.2 Input List for Subroutine HPCALC

The basic dimensional data computed in Subroutine DIM is required as input for HPCALC and it is available in common storage.

BS. . . . . LC(GG)	PC . . . . LC(CC)
DH . . . . LC(GG)	SEP. . . . . LC(JJ)
H . . . . LC(JJ)	XF . . . . LC(JJ)
LEN . . . . LC(BB)	XLS . . . . LC(GG)

6.5.3 Program Development

A detailed description of the complete DRAG program is to be found in reference (22). To provide insight into what the routine does, the steps of the calculation will be summarized here. First the dimension data are transferred from storage and other dimensions required in the routine are computed. Then the volume and surface area of each of the submerged components of the ship is calculated. It is assumed that the displacement generated in this calculation is more accurate than that approximated in the dimension routine and this value of displacement replaces the test value in storage. Wind drag of the box structure is computed next. Then an eddy making drag term is computed for the struts. A velocity loop is started which will calculate the drag values at speeds from 6 to 33 knots in 3 knot increments. Wave-making resistance is estimated using a 400 term expansion. Then frictional resistance coefficients for the hull parts are estimated. Schoenherr friction and a ΔCF value of .0005 are used. A 10 percent addition to hull friction drag is applied to account for eddy-making. The final resistance component estimated in this routine is spray drag from the struts. Then the drag components are summed, a 6 percent allowance added for appendages and a horsepower value is computed as a function of the input propulsive coefficient for each speed generated in the loop. The looping on speed continues until the DO parameter is satisfied and

the POW and VKNTS arrays are filled with values of shaft horsepower and speed, respectively. A user of this routine is cautioned that any change in the speed values desired as output necessitates a change in the speed DO loop and the dimensions of the arrays for storing the horsepower and speed data as well as the dimension of the coefficient arrays for storing the horsepower and speed data as well as the dimension of the coefficient array for the spline cubic curve fitting routine, UGLYDK, used in subroutine XECUTE. It is felt that the range of speed values calculated by the existing program is sufficient for the required operating speeds for Coast Guard SWATH applications.

6.5.4 Flow Chart

A simplified flow chart of the HPCALC subroutine showing the order and type of calculations performed is shown in Figure 10.

6.5.5 Output List for Subroutine HPCALC

TONS. . . . . LC(GG)

POW(12). . . . . LC(SS)

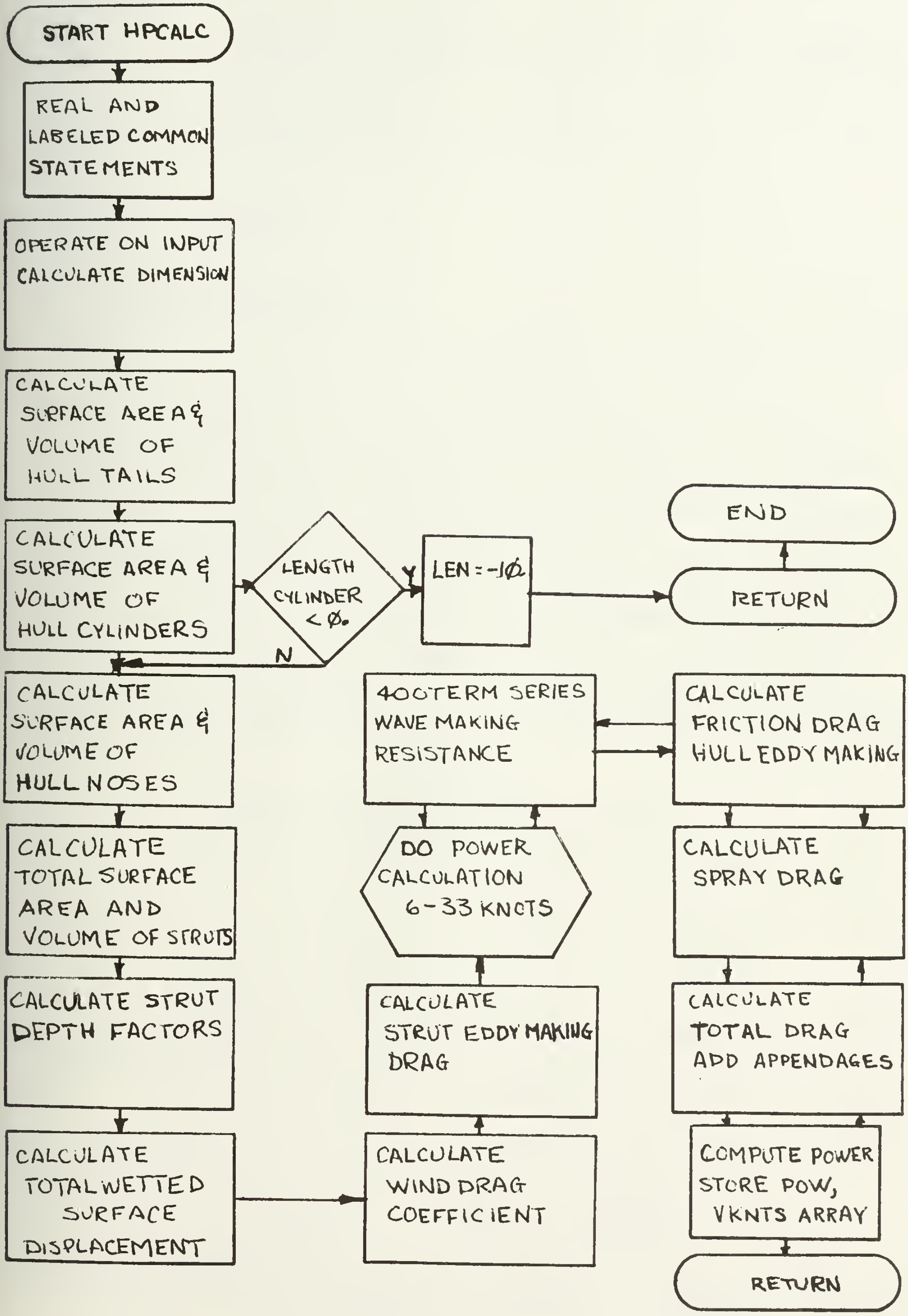
VKNTS(12) . . . . LC(SS)

6.5.6 Nomenclature List

There are a large number of variables defined within this subroutine. With the exception of those listed below, each of these variables is defined by a comment card in the program listing, is not used elsewhere in the model, and therefore will not be listed in this section.

CA	length of the strut-in feet - XLS in MAIN
EFGH	depth of box for wind drag calculation, feet - DB in MAIN

FIGURE 10: HPCALC SUBROUTINE FLOW CHART



TA	strut beam in feet - BS in MAIN
TONS	displacement, tons - DPTRY in MAIN
W	width of channel used in wave-making resistance estimate, ft
XA	distance from tail to center of strut, feet - XF in MAIN

6.6 Subroutine EPLANT

6.6.1 Purpose and Approach

This subroutine performs two functions. It estimates the average electrical plant load for use in estimating the fuel requirements for providing electrical energy to the ship and it calculates the size of generator needed for installation on the ship based on the expected loads with appropriate margins. Both of these outputs are useful in the preliminary design phase. The EPLANT routine follows Goodwin's routine with modification to provide for SWATH options. Goodwin's data for conventional ships and data for one SWATH design are shown in Table III.

TABLE III

ELECTRICAL LOAD DATA IN KW

Ship	150 WPB	210 WMEC	378 WHEC	240 AGOR
Electronics	4.8	21.99	117.84	72.00
Armament	42.7	0.0	46.64	0.0
Propulsion Auxiliaries	1.02	.71	71.03	15.00
Air Conditioning and Ventilation	21.1	49.13	308.34	190.00
Hotel	20.9	35.4	171.51	88.00
Other Auxiliaries	19.8	46.76	113.08	204.00
Steering Gear	.54	4.48	37.38	
Auxiliary Machinery	18.26	40.08	70.72	110.
Shops	1.0	2.2	4.98	
Mission Related				94.
	110.32	153.99	827.44	569.00

6.6.2 Input List for Subroutine EPLANT

Electronics and armament electrical loads, whether the machinery plant auxiliary load is specified and what that load is, the type of machinery plant and the crew size are inputs through the MAIN program. Cubic number is estimated in the MAIN program and used in EPLANT. The following is the input list:

BLOAD.	LC(DD)	NCPO.	LC(AA)
CN.	LC(BB)	NENL.	LC(AA)
ELOAD.	LC(DD)	NOFF.	LC(AA)
JOPT	LC(CC)	PALOAD.	LC(AA)
MTYPE	LC(CC)		

6.6.3 Program Development

In using Goodwin's electric plant sizing relationships as a starting point for a SWATH model it is assumed that the requirements of Coast Guard operated SWATHs will be similar to that of conventional ships and that the parameters used by Goodwin apply to SWATHs. This routine assumes that the electronics and armament loads are input. Then the propulsion auxiliary load is estimated. For diesel propulsion a value of 1 KW is assumed for equipment directly related to the operation of the main propulsion machinery. For diesel electric propulsion a value for propulsion auxiliaries of 15 KW is used based on data from the AGOR SWATH estimates. For gas turbine plants and gas turbine electric plants a value of 71 KW is used. If the JOPT option is used with propulsion data as input, the input value of propulsion auxiliary load is used.

Air conditioning loads are estimated as a function of cubic number times the number of accommodations. This relation is shown in Figure 11. Note that the one SWATH point falls well off the estimating curve. This ship has the volume sufficient for a crew of approximately 100 if military standards are used, yet its crew is 49 and the arrangements are more nearly commercial practice. If the crew size were doubled on this ship, its data point would fall very nearly on the estimator.

Hotel loads, which consist of galley and lighting loads, are estimated as a function of the number of accommodations. This relation is shown in Figure 12. Again note that the one SWATH point is well off the estimator but if the crew size is brought more in line with military practice, the point will fall nearly on the line.

Other auxiliary loads are estimated as a function of cubic number. This relation is shown in Figure 13. Note that the SWATH point falls near the line if a large portion of the mission related loads, which are considerable on this ship, are removed from the relation.

The total electrical load computed is the sum of the electronics, armament, propulsion auxiliaries, air conditioning and ventilation, hotel and other auxiliaries loads with a two percent growth margin on all equipment and a 100 percent margin on electronics. The average load for determining fuel requirements is the total load without margins minus armament. An additional factor of 25 percent is included to allow for starting loads and deterioration.

Three diesel generators, each of which is capable of carrying the entire ship load, are assumed in this model. The smallest generator

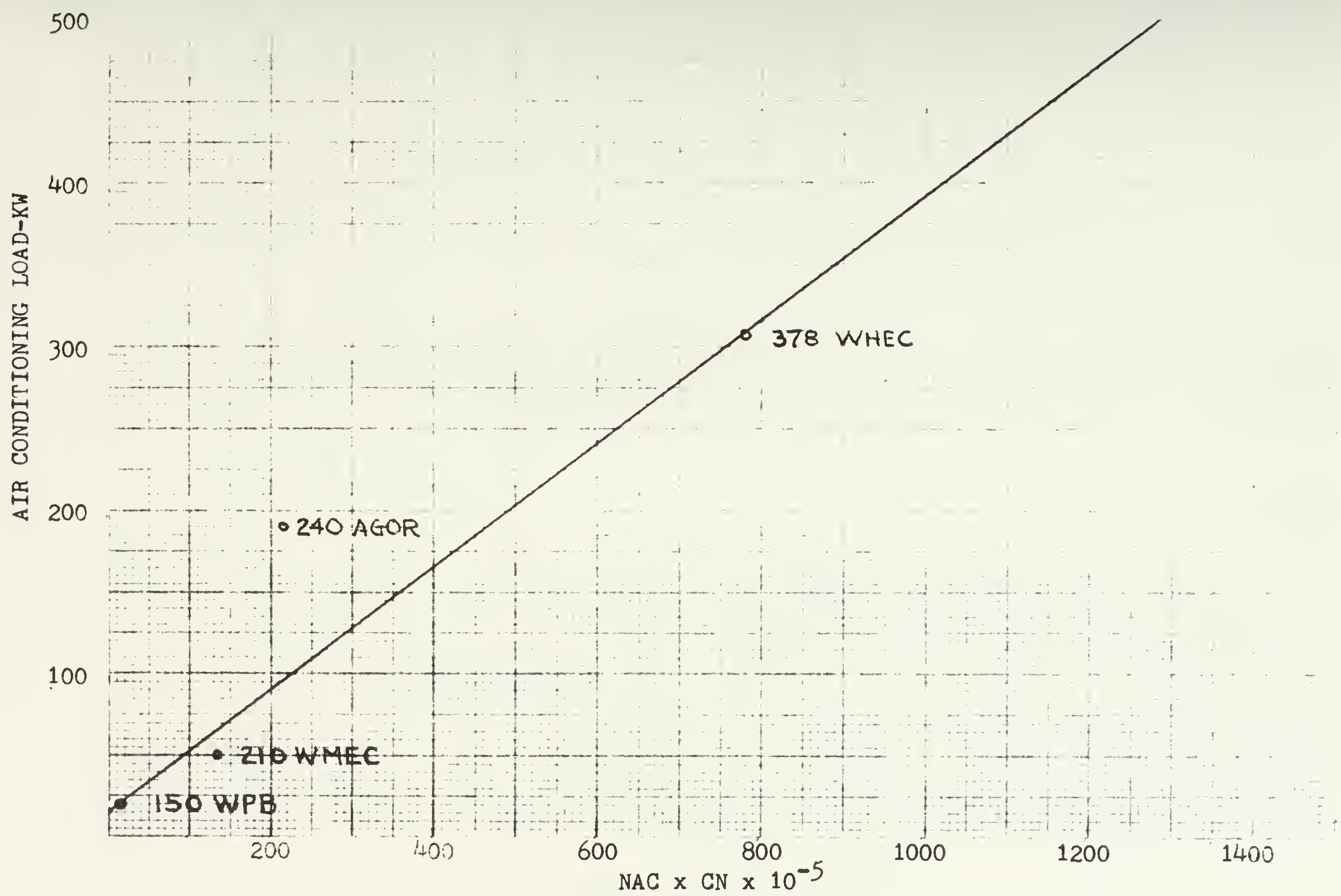


FIGURE 11: AIR CONDITIONING LOAD VERSUS NAC x CN x 10^{-5}

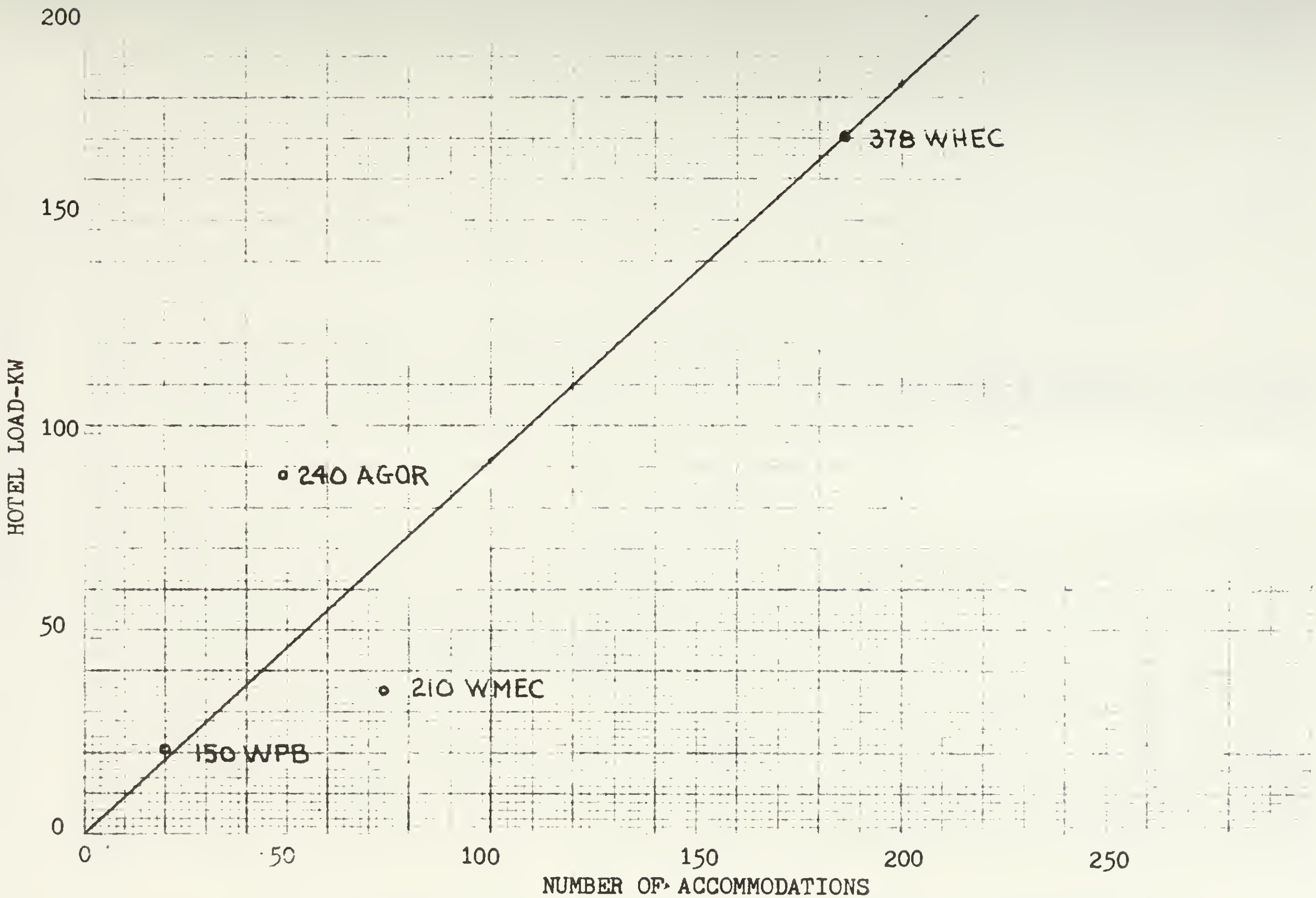


FIGURE 12: HOTEL LOAD VERSUS NUMBER OF ACCOMMODATIONS

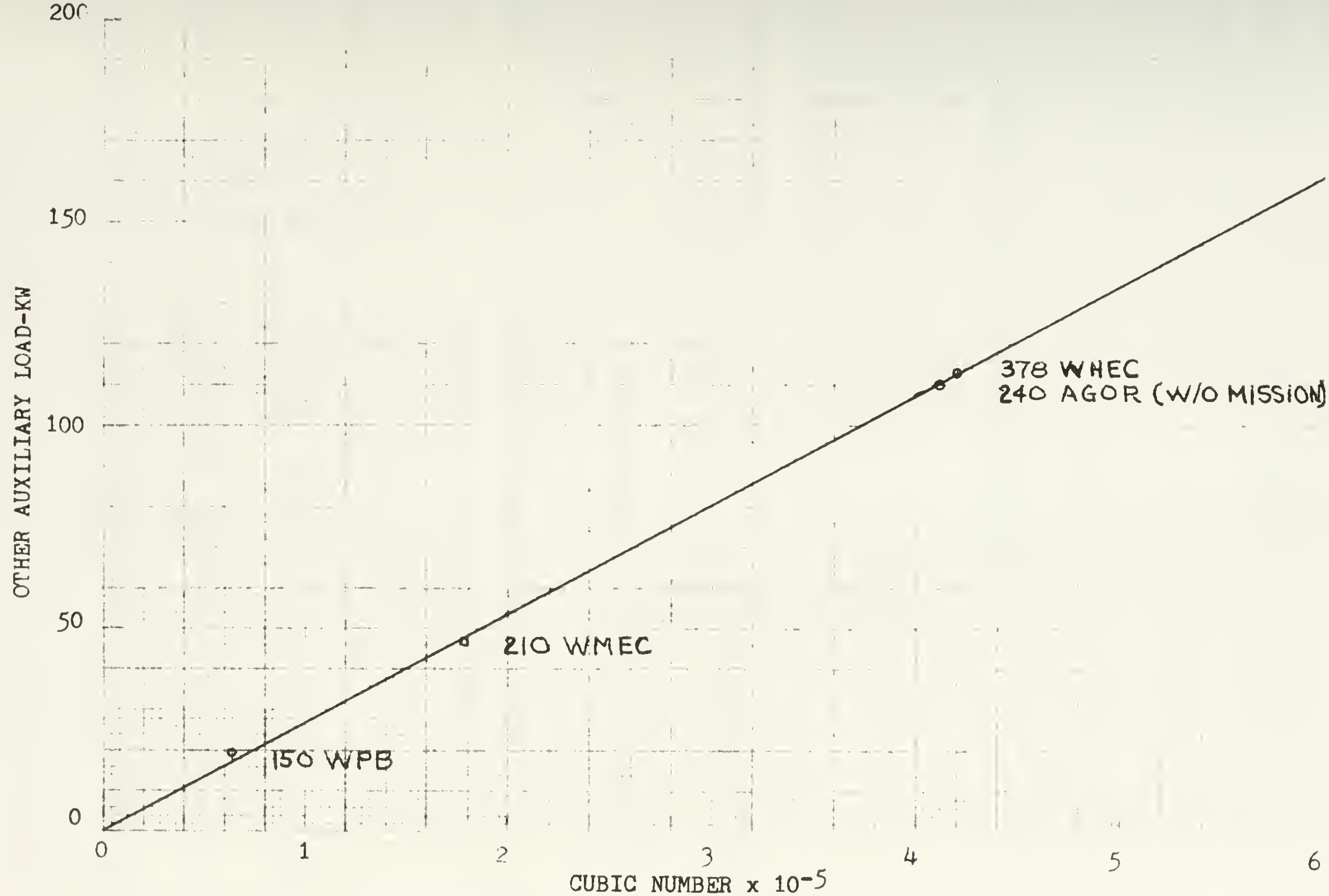


FIGURE 13: OTHER AUXILIARY LOAD VERSUS CUBIC NUMBER x 10^{-5}

size to be installed is assumed to be 100 KW. Other possible plant sizes are between 100 and 250 KW in 50 KW increments, between 250 and 1000 KW in 250 KW increments and above 1000 KW in 500 KW increments. The final section of the subroutine chooses the smallest generator capable of supplying the load.

6.6.4 Flow Chart

A flow chart of this routine is shown in Figure 14.

6.6.5 Output List for Subroutine EPLANT

AVKW . . . . LC(DD)

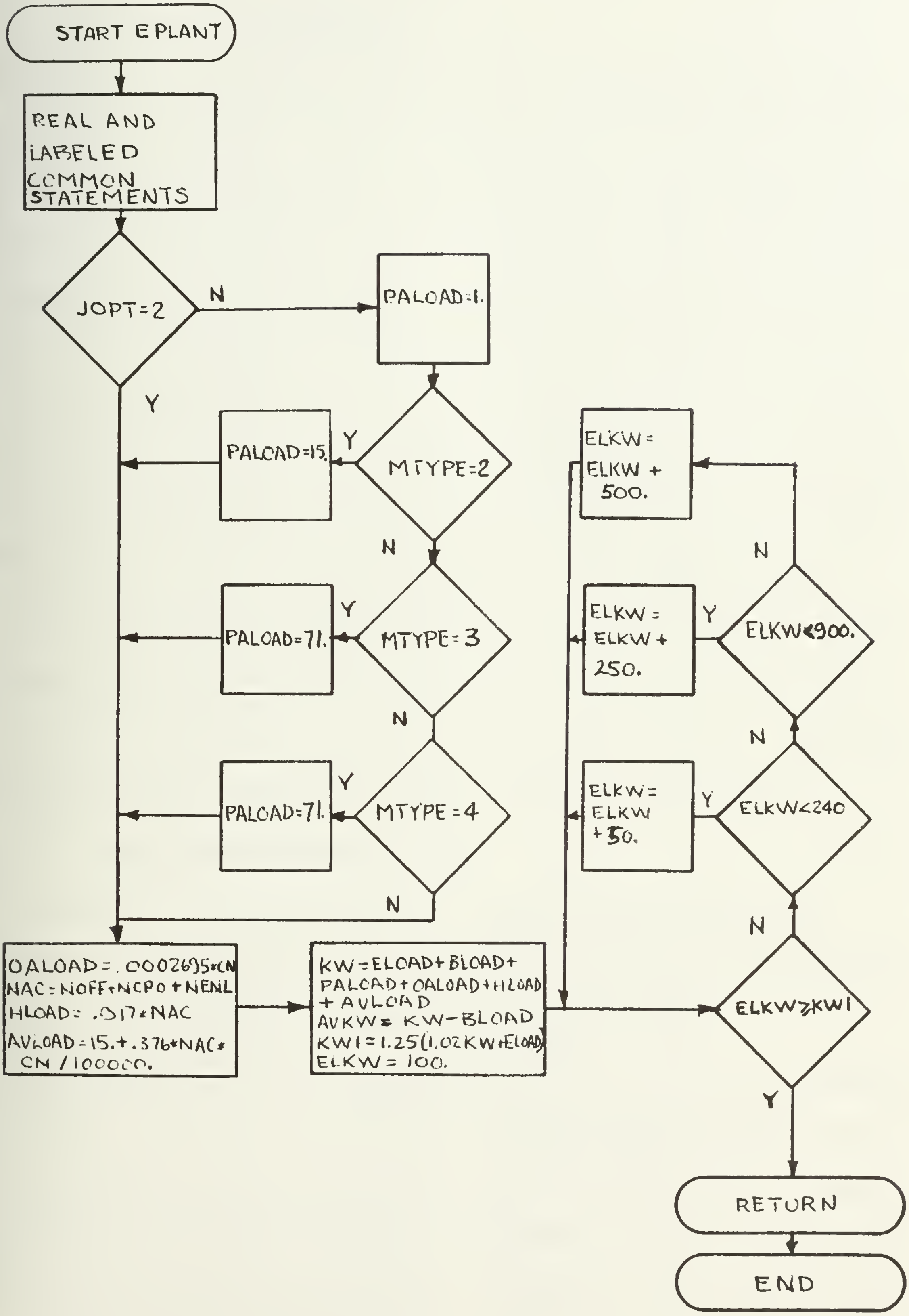
ELKW . . . . LC(DD)

6.6.6 Nomenclature List

All variables have the same definition as given in the MAIN program nomenclature with the exception of the following:

AVLOAD	air conditioning and ventilation load, KW
HLOAD	hotel load, KW
KW	total load without margins, KW
KW1	total load with margins, KW
NAC	number of accommodations
OALOAD	other auxiliaries load, KW
RE	endurance range, nautical miles - RGEND in MAIN
SFCH	specific fuel consumption at half power - SFCHHP in MAIN
SFCM	specific fuel consumption at maximum power - SFCMHP in MAIN
VE	endurance speed, knots - VEND in MAIN

FIGURE 14: EPLANT SUBROUTINE FLOW CHART



6.7 Subroutine LIQ

6.7.1 Purpose and Approach

The shaft horsepower and size of the electrical plant have been determined for the ship. With this information the weight of required fuel, lubricating oil and potable water can be calculated. Subroutine LIQ estimates the endurance power specific fuel consumption, SFC, in pounds per shaft horsepower - hour, calculates, the required fuel weight to meet endurance requirements, calculates lubricating oil weight as a function of machinery type and horsepower and calculates potable water weight as a function of crew size. If a specific machinery plant is input, the input description includes the specific fuel consumption at half and full power. These data are used to estimate the endurance fuel requirements.

Data on specific fuel consumption as functions of horsepower and machinery type are compiled and linear approximations of variation of specific fuel rate between half and full power were computed. This data and the associated equations are shown in the following sections.

6.7.2 Input List for Subroutine LIQ

Crew size, electrical load data, endurance range and speed, horsepower required for speeds and machinery type are required inputs. If JOPT equals 2 the specific fuel consumptions are input.

AVKW . . . . LC(DD)
JOPT . . . . LC(CC)
MTYPE . . . . LC(CC)
NCPO . . . . LC(AA)
NENL . . . . LC(AA)
NOFF . . . . LC(AA)

RE . . . . LC(CC)
SFCH (JOPT=2 only) . . LC(CC)
SFCM (JOPT=2 only). . LC(CC)
SHPE . . . . LC(CC)
SHPM . . . . LC(CC)
VE . . . . LC(CC)

6.7.3 Program Development

Gas Turbine specific fuel consumption data were gathered and analyzed. The gas turbine horsepower range was divided into three categories and specific fuel consumption relationships were computed for for each horsepower range based on the data. The three horsepower ranges are representative of small, medium and large marine gas turbines and include both first and second generation turbine data. For diesel propulsion it is assumed that the SFC at full power is 0.42 pounds per shaft horsepower-hour and at half power, 0.46 pounds per shaft horse-power-hour. For the electric power options an efficiency of 0.97 is assumed for the motors and generators, respectively and 0.98 for the connections; this results in an overall loss of 8.5 percent. Experimental values from existing installations indicate that the electrical losses are approximately six and fifteen percent for alternating and direct current systems, respectively. In this model linear relationships between the full and half power point specific fuel consumptions are assumed. No allowance for the possibility of cruising on one shaft at endurance speed is made for the gas turbine or gas turbine-electric configurations, but a fuel saving for reducing the number of connected diesel engines is assumed. Table IV summarizes the assumed values of specific fuel consumption for machinery types and horsepowers. These specific fuel consumption estimates lead to the following equations for estimating the endurance fuel consumption. For Diesel propulsion systems:

SFC = 0.5-0.08*SHPE/SHPM

TABLE IV

FUEL RATE ASSUMPTIONS

MACHINERY TYPE	NOMINAL HORSEPOWER	SFCM	SFCH
GAS TURBINE	More Than 30000	.40	.49
FT 9	35000	.391	.491
FT 4 A-2	25500	.475	-
LM 2500	24050	.393	.474
GAS TURBINE	8000 - 30000	.56	.64
LM 1500	14300	.56	.64
GAS TURBINE	Less Than 8000	.57	.71
GTP 990	5000	.473	-
TYNE	4000	.50	-
PROTEUS	3000	.66	-
TF 35	2750	.571	.71
LM 100PJ102	1150	.629	.809
GAS TURBINE-ELECTRIC	More Than 30000	.43	.53
GAS TURBINE-ELECTRIC	8000 - 30000	.61	.69
GAS TURBINE-ELECTRIC	Less Than 8000	.62	.77
DIESEL	3500	.42	.46
DIESEL-ELECTRIC	3500	.46	.50

For Diesel propulsion systems where the maximum horsepower exceeds 7000 and the endurance horsepower is less than half the maximum horsepower:

SFC = 0.5-0.16*SHPE/SHPM

For Diesel-electric propulsion:

SFC = 0.54-0.08*SHPE/SHPM

For Diesel-electric propulsion with low endurance horsepower requirement:

SFC = 0.54-0.16*SHPE/SHPM

For gas turbine propulsion with maximum horsepower required less than 8000:

SFC = 0.85-0.28*SHPE/SHPM

For gas turbine propulsion in the 8000 to 30000 horsepower range:

SFC = 0.64-0.16*SHPE/SHPM

For gas turbine propulsion above 30000 horsepower:

SFC = 0.49-0.18*SHPE/SHPM

For gas turbine-electric propulsion of less than 8000 horsepower:

SFC = 0.92-0.30*SHPE/SHPM

For gas turbine-electric propulsion in the 8000 to 30000 horsepower range:

SFC = 0.77-0.16*SHPE/SHPM

For gas turbine-electric propulsion above 30000 horsepower:

SFC = 0.63-0.20*SHPE/SHPM

If the maximum horsepower and half power specific fuel consumption values are input the following relation is used to determine the fuel consumption at endurance speed:

SFC = SFCM + (1.-SHPE/SHPM)*2.(SFCH-SFCM)

The specific fuel consumption of the main propulsion machinery is added to the specific fuel consumption for ship service generators and the fuel consumption for hotel services to determine the total fuel rate. The specific fuel consumption for the ship service generators is assumed to be about 0.48 pounds per shaft horsepower-hour or 0.65 pounds per kilowatt hour. Fuel consumption for the generators is calculated using the average electrical load. Fuel consumption for hotel services is taken as 0.32 pounds per man-hour and assumes some waste heat recovery. The total weight of fuel is calculated as the total fuel rate time the endurance is nautical miles times a fouling allowance times a degradation allowance times a torsion meter correction times a tail pipe allowance divided by the endurance speed in knots and 2240 to convert to tons. Thus,

WTFUEL = FR*RE(1.1)(1.05)(1.03)(1/.95)/(2240.*VE) = FR*RE/(1788.*VE)

Lubricating oil requirements are assumed to be five tons plus one ton per thousand horsepower for any Diesel plant or three and one half tons plus one ton per ten thousand horsepower for all gas turbine plants. Potable water requirements are taken as fifty gallons per man or 0.186 tons per man.

6.7.4 Flow Chart

A flow chart of this routine is shown in Figure 15.

6.7.5 Output List for Subroutine LIQ

WTFUEL . . . . LC(LL)

WTLO . . . . LC(LL)

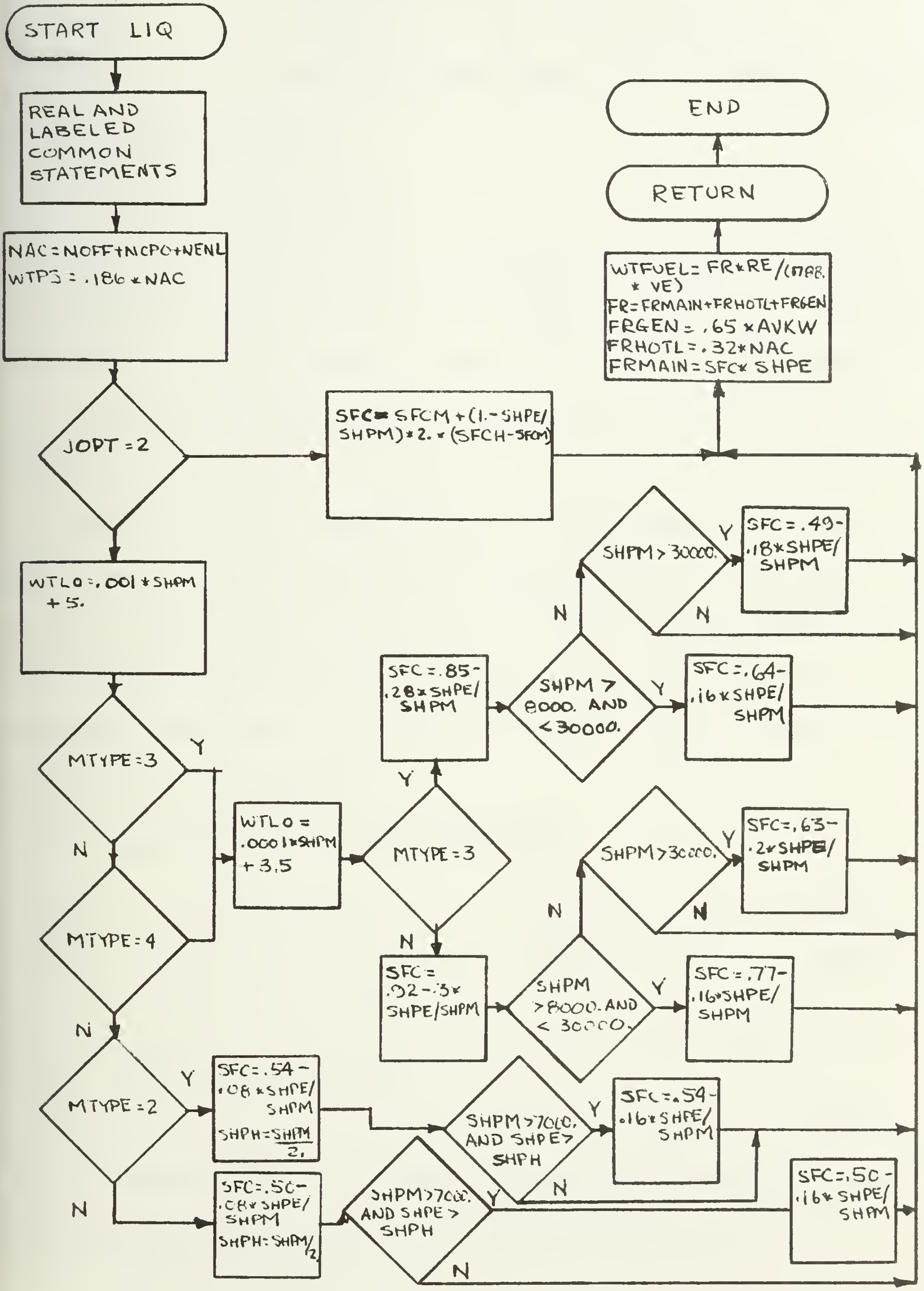
WTPS . . . . LC(LL)

6.7.6 Nomenclature List

All variables have the same definitions as given in the MAIN program nomenclature with the exception of the following:

FR	total fuel rate in pounds per hour
FRGEN	generator fuel rate in pounds per hour
FRHOTL	hotel fuel rate in pounds per hour
FRMAIN	main engine fuel rate in pounds per hour
NAC	number of accommodations
RE	endurance range, nautical miles - RGEND in MAIN
SFC	specific fuel consumption at endurance power, lbs/SHP-hr
SFCH	specific fuel consumption at half power - SFCHHP in MAIN

FIGURE 15: LIQ SUBROUTINE FLOW CHART



SHCM	specific fuel consumption at maximum power - SFCMHP in MAIN
SHPH	one half of maximum shaft horsepower
VE	endurance speed, knots - VEND in MAIN

6.8 Subroutine MACHBX

6.8.1 Purpose and Approach

Based on the machinery type selected, the shaft horsepower and the ship dimensions, the location and dimensions of the prime mover and power transmission machinery spaces are estimated and assigned. If the machinery space dimensions are input, this routine is not executed.

There is very little data available on SWATH machinery spaces. Table V summarizes available data. Because of the lack of data, the approach to this routine has been a best reasonable estimate taking into account obvious volume requirements of the machinery but doing few calculations. The results are therefore only estimates to be used in the remainder of the program.

6.8.2 Input List for Subroutine MACHBX

BS . . . . LC(GG)

DB . . . . LC(JJ)

DH . . . . LC(GG)

MTYPE . . . . LC(CC)

SHPM . . . . LC(CC)

6.8.3 Program Development

Subroutine MACHBX proceeds from several important assumptions. First the feasible range of ship dimensions and required horsepower given in the limits of Subroutine XECUTE eliminates combinations of

TABLE V

MACHINERY SPACE DATA

MACHINERY PARAMETER	SHIP 3	6	18	24
Machinery Type	3	3	3	3
Location Prime Mover	Hull	Hull	Box	Hull
Location Aux. Space	Hull	Hull	Hull	2nd Dk Bx
	Hull	Hull	Hull	2nd Dk Bx
	Box	Box	Box	
Dimensions Prime Mover (L x W x D) FT	56x19.2x19.2	56x19x19	40x51x9	35x15x15
Dimensions Aux. Space	32x19.2x19.2	40x19x19	80x13x13	43x20x9
	32x19.2x19.2	40x19x19	80x13x13	43x20x9
	96x54x9	96x60x9	40x46x9	
Volume Machinery Spaces	103621	110814	74850	27850
Volume Aux. Spaces (cu. ft.)	66561	74522	37664	15480

Volume Machinery Spaces = Total Machinery and Auxiliary Machinery Spaces, Both Hulls Plus Box.

design variables which are not feasible and prevents further execution of the program. If a feasible set of ship dimensions has been generated and the machinery space dimensions are not inputs, MACHBX is executed. Machinery may be located in the hulls, the struts or in the box of a SWATH. A code is used to determine where parts of the propulsion system are located. MBLOC1 is the code for the transmission and propulsor device, that is, the gears shafting and propeller or the electric motor, shafting

and the propeller. MBLOC2 is the code for the prime mover. A value of 1 for these codes implies that the machinery system part is in the hull; a value of 2 for these codes implies that the machinery system part is in the box. Thus, MBLOC2=1 implies that the prime mover is in the hull. The only valid value of MBLOC1 in this model is MBLOC1=1; the propeller, shaft and gears must be in the hull. When electric propulsion is specified, the model assumes that the prime movers are in the box and the motors in the hulls. For Diesel propulsion the model assumes that the prime movers will be in the box if the required horsepower exceeds 7000 and that a gear and shaft system will transfer the power to the hulls. This model assumes that there will always be a large auxiliary machinery space located in the box which will be used for generators and auxiliary machinery. The data in Table V indicate the size of previous SWATH auxiliary spaces. The requirements for auxiliary spaces are satisfied in Subroutine VOLUME.

Specific assumptions made in the routine for expressing the machinery space dimensions are functions of horsepower, machinery type and geometry too. The minimum power transmission space length is taken as 25 feet and the height and width of that space are the diameter of the hull. The minimum length for a Diesel engine space is assumed to be 28 feet. For electric propulsion requiring more than 30000 horsepower, it is assumed that two motor armatures will be mounted on a common shaft and the length of the power transmission space is doubled. To determine the required length of gas turbine engine spaces, a curve was constructed expressing the length of gas turbine engines as a function of horsepower and adding 10 feet to account for ducting. The equation for the length of gas turbine is:

LENGTH = 10. + .00048 * SHP

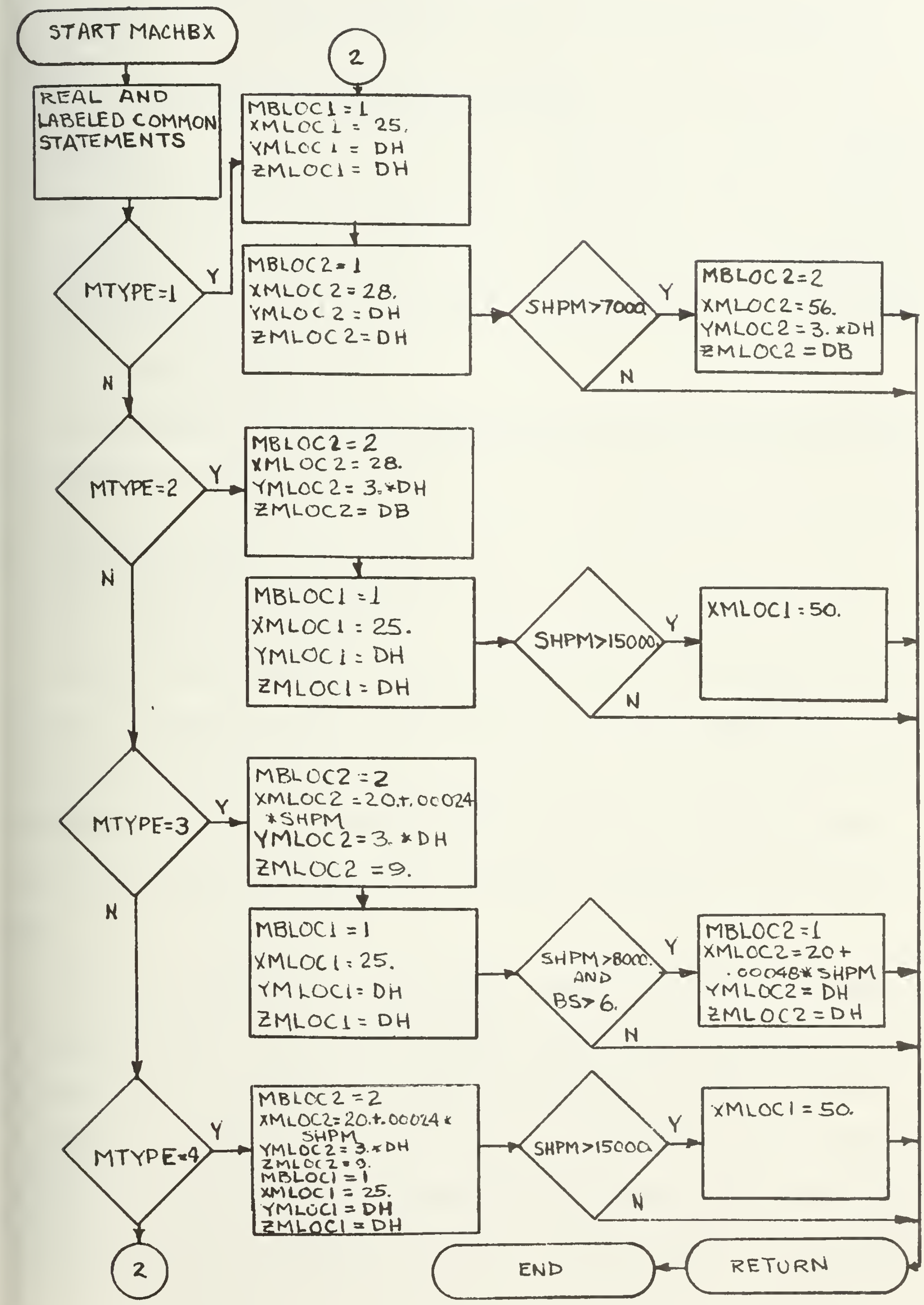
When corrected for the total shaft horsepower and for ducting the form of the equation used in the model is:

XMLOC2 = 20. + .00024*SHPM

Additional allowances are made for large gas turbine engines in the hulls. The program also assumes that small gas turbines are located in the box and drive the propulsor through a gear or chain drive. If the gas turbine total horsepower exceeds 8000 and the width of the strut is sufficient to provide for access and removal, 6 feet, then the gas turbine is placed in the hull. An analysis of rough arrangements of three Navy designs indicated that the dimensions of machinery spaces in the box could be approximated by setting the machinery space length equal to the Diesel engine minimum for Diesel propulsion or to the gas turbine length estimated above, the machinery space width could be approximated by three times the hull diameter and the height could be set equal to 9 feet for gas turbines and the box depth for Diesels.

The subroutine first tests to determine the type of machinery which has been specified and directs execution of a series of statements which estimate the dimensions. Within each set of dimension-estimating statements, tests are carried out on the geometry and horsepower to determine whether the estimates should be modified before completion of the routine. The length, width and height dimensions for the two machinery spaces are calculated and stored in a common storage location.

FIGURE 16: MACHBX SUBROUTINE FLOW CHART



6.8.4 Flow Chart

A flow chart for the MACHBX routine is shown in Figure 16.

6.8.5 Output List for Subroutine MACHBX

MBLOC1. . . . . LC(JJ)	YMLOC1. . . . . LC(QQ)
MBLOC2. . . . . LC(JJ)	YMLOC2. . . . . LC(QQ)
XMLOC1. . . . . LC(QQ)	ZMLOC1. . . . . LC(QQ)
XMLOC2. . . . . LC(QQ)	ZMLOC2. . . . . LC(QQ)

6.8.6 Nomenclature List

All variables used in this routine have the same definitions listed in the MAIN program.

6.9 Subroutine VOLUME

6.9.1 Purpose and Approach

Many modern ships are volume limited rather than weight limited. However, the SWATH ship is more likely to be weight limited than volume limited due to the large box-like cross structure of the box and the lack of waterplane area for controlling sinkage and trim. This subroutine balances the volume required and the volume available for the SWATH ship.

The basic dimensions of the entire ship have already been determined in Subroutine DIM. Subroutine VOLUME checks for the arrangement of various volume groups and increments the number of decks in the box or adjusts the deckhouse volume to attain a volume check. The volume groups are divided among the components of the ship. Hull volume, strut volume, box volume, deckhouse volume and total volume are computed

separately and then summed. It is assumed that the hulls may be used for machinery spaces, liquid tanks, steering gear and control fin actuator spaces only. The struts are assumed to have one useable platform over 75 percent of the length, access spaces, uptakes and fuel overflow tanks. The remainder of the volume in the struts is assumed to be inaccessible voids. The box volume is assumed to be used for arrangements and for machinery spaces. The box is provided with a double bottom which is not available for arrangements. The deckhouse is assumed to contain the pilothouse, Combat Information Center, Captain's Quarters and all areas specified in the input of payload, armament and electronics equipment which were to be in the deckhouse. No sheer is assumed. No raised decks may be added over a fraction of the length of the box; a complete deck must be added for structural reasons. The assumed deck height is 9 feet. The requirement for addition of a complete deck if a space balance cannot be achieved by varying the deckhouse size alone means that there is a step function of volume and that it is likely that excess volumes will be produced by this model.

6.9.2 Input List of Subroutine VOLUME

AG	LC(JJ)	DH	LC(GG)
AREADH	LC(BB)	H	LC(GG)
AREAHL	LC(BB)	JOPT	LC(CC)
BBOX	LC(GG)	LEN	LC(BB)
BS	LC(GG)	MBLOC1	LC(JJ)
CWP	LC(GG)	MBLOC2	LC(JJ)
D	LC(AA)	NCPO	LC(AA)

NENL. . . . . LC(AA)	XLS. . . . . LC(GG)
NOFF. . . . . LC(AA)	XMLOC1 . . . . LC(QQ)
WACFUL . . . . LC(LL)	XMLOC2 . . . . LC(QQ)
WTFUEL . . . . LC(LL)	YMLOC2 . . . . LC(QQ)
WTLO . . . . LC(LL)	ZMLOC2 . . . . LC(QQ)
XLB . . . . LC(JJ)	

6.9.3 Program Development

The SWATH ship dimensions determined by Subroutine DIM and input to this subroutine are average SWATH dimensions based on previous design studies. These dimensions and the assumptions made completely determine the enclosed volume except for the deckhouse volume variable and the number of decks variable. The deckhouse volume is computed early in the routine and adjusted to attain a volume check. To do this, the maximum value of deckhouse volume based on previous SWATH designs is used as an upper limit. Deckhouse volume is constrained by stability requirements and secondarily by required deck area on a conventional ship. In a SWATH configuration the stability requirement and the deck space requirements are not as controlling because of the wide spacing of hulls and wide rectangular decks. Deckhouse volume limitations have been included in this model and are shown in Figure 17. The program starts by assuming the maximum deckhouse volume in the range: $DHV = .007*LEN^3$ and if the volume available which is computed at the end of the program is excessive, the deckhouse volume is reduced as necessary down to the minimum value of $DHV = .000223*LEN^3$. The minimum line used by Goodwin, $DHV = .000151*LEN^3$, is also shown on Figure 17. If the required volume is not sufficient with the maximum

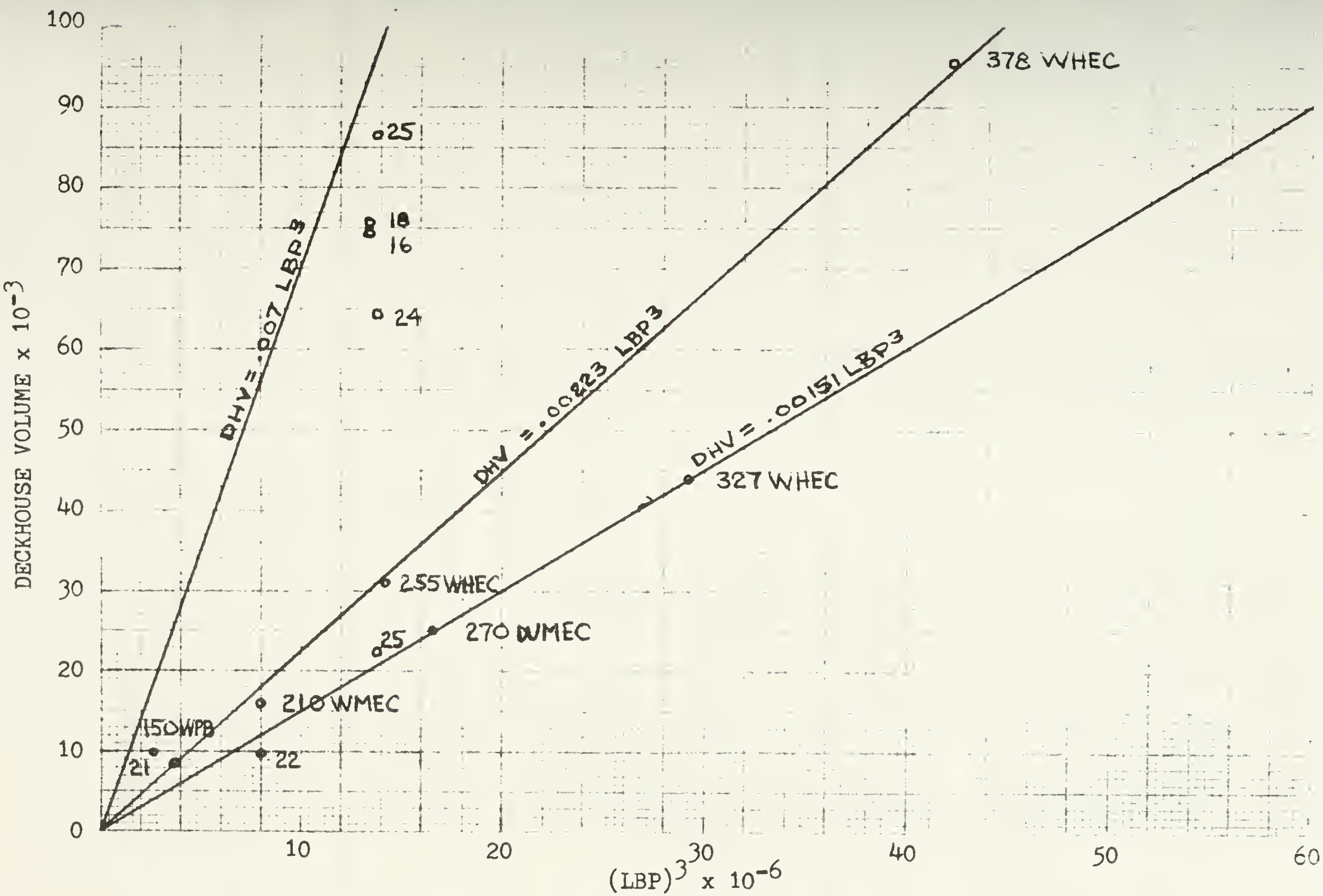


FIGURE 17: DECKHOUSE VOLUME VERSUS $(LBP)^3$

deckhouse size, the program will increment the number of decks and recompute the areas. A maximum limit of two decks in the box is allowed.

The program procedes through the calculation of volume in the following manner. First the hull volume is recomputed. Then the liquid volumes are computed and multiplied by a factor of 1.2 to account for structure, expansion and overflow. The volume of machinery spaces is next computed. The total volume of the ship is computed and the deckhouse volume is subtracted from this number to determine the cubic number which is used as a variable in sizing the steering machinery and fin control actuator spaces. Based on limited SWATH data and recalling that the SWATH requires a rudder for each hull and a number of control surfaces for motions control, the deck area for steering gear is taken as three times that used in the cutter model and the volume of steering gear is taken as the deck area times deck height. The required volume of the hulls is the sum of tankage volume, steering gear volume and any machinery space volume to be placed in the hull. If the hull volume is insufficient, liquid overflow tanks are allowed to fill up to 30 percent of the strut volume. It is not expected that this liquid overflow tank alternative will be used but it is provided as a safety feature in the program. After the hull volumes are checked, the required deckhouse area is computed and checked with the available area. If the requirements are larger than the available area the program returns an error message. Otherwise the program computes the arrangements area of the struts and the box and adds this arrangement area to the area in the deckhouse to determine the total available arrangements area.

The next section of the routine lists the estimating relationships used for computing the required areas for each of many ship functional areas. In general the relationships developed by Goodwin from Coast Guard Cutter data have been retained in this model, however several adjustments have been made to reflect SWATH differences or more modern data. The first exception to the Goodwin relationships comes in computing the area required for other stores, OSDA. Recent data and an apparent trend towards shorter endurance periods and more land-based support indicates that Goodwin's values are excessive and 75 percent of these values are used in this model. A study of the machinery space requirements of a SWATH indicates that the size of auxiliary machinery spaces is larger than for a conventional ship. A correction for this was considered in the MACHBX subroutine preparation and the expression AUXVOL = 13178 + .4755*SHPM was derived. Further study showed that auxiliary spaces are strongly dependent on ship volume and a relationship similar to Goodwin's but increased by a factor of approximately two was found to fit the data well. Therefore the expression

AMDA = .0097*CN

was used in this model. SWATHs appear to require more deck area in passages than conventional ships; a passageway factor of 10 percent is used in this model. Repair lockers are fixed at 145 square feet of deck area in this model. Uptakes and access to the hulls are sized if the machinery specifications are not input. If the prime movers are in the hulls, 700 square feet is allotted to uptakes; if the prime movers are in the box, 200 square feet are allotted to uptakes. If the prime movers

are in the box, space is reserved for machinery in the box arrangement by the expression

VMXA = VMX/9.

SWATHs require additional space for mooring stations near the sides of the ship at the dock level; in general lines cannot be handled exclusively from the main deck. The model allows for additional mooring station space as

WSDA = 5.*LEN-475.

After all requirements have been computed the total required area is calculated and compared against the available area. If the area available is too small, the deck increment is added and the routine recycles; if the available area is too large, the deckhouse volume is reduced until a balance is reached or the minimum deckhouse size is reached. At this point the volume balance is completed and control is returned to XECUTE.

Data for space allocation which forms the basis for the estimating relationships used in subroutine VOLUME is shown in Table VI. This data includes some data used by Goodwin and new data from SWATH design and Coast Guard conventional design. Figures 18 through 22 show the linear relations developed for estimating areas.

6.9.4 Flow Chart

A flow chart of the VOLUME routine is shown in Figure 23.

TABLE VI

ARRANGEMENT AREA DATA

CATEGORY	378 WHEC	327 WHEC	270 WMEC	210 WMEC	240 AGOR SWATH
Office Spaces	493	465	432	130	266
Messing Facilities	2713	2348	1771	1452	1491
Crew Special	725	609	482	324	599
Officer Staterooms	1157	1338	983	567	1956
Officer Sanitary	243	133	181	193	345
CPO Staterooms	1040	364	418	283	270
CPO Sanitary	250	100	168	75	66
Crew Berthing	3641	2655	1097	1658	2300
Crew Sanitary	716	444	530	384	530
CO Stateroom & Cabin	697	511	204	406	336
CO Pantry	58	128	-	-	-
Commissary Stores	600	724	160	480	501
Other Stores	3015	2354	1780	1294	1681
Workshops	1161	818	954	544	176
Passages	2567	2588	2251	739	2481
Repair Lockers	148	18	183	110	180
Steering Gear & Windlass	736	548	739	270	2872
Chain Locker	47	30	33	42	56
A/C & Fan Spaces	369	324	239	165	462
I.C. & Gyro Room	312	143	-	180	442
Aux. Machinery Spaces	1860	1874	1532	820	4714
Uptakes (Hull)	462	1216	536	-	-
Pilothouse, Chartroom & C.I.C.	1125	856	730	422	1055
SUB TOTAL	24135	20588	15403	10538	22752
EXTRAS					
Crew Recreation Rooms	1445	-	1390	-	236
Cargo & Flume Tanks	1219	249	-	-	-
Electronics & Stores	1618	775	1384	319	-
Armament & Stores	844	822	451	280	-
Balloon Shelters	512	156	1074	-	-
Mission Offices & Labs	746	336	-	-	2418
Mission Workshops	-	-	-	105	1134
Bow Thruster	344	-	-	-	-
TOTAL	30863	22926	19704	11242	26540

Messing Facilities = Wardroom, Pantry, CPO Mess, Crew Mess, Galley, Scullery.

Crew Special = Sick Bay, Barbershop, Movie Locker, Laundry, Ship Store.

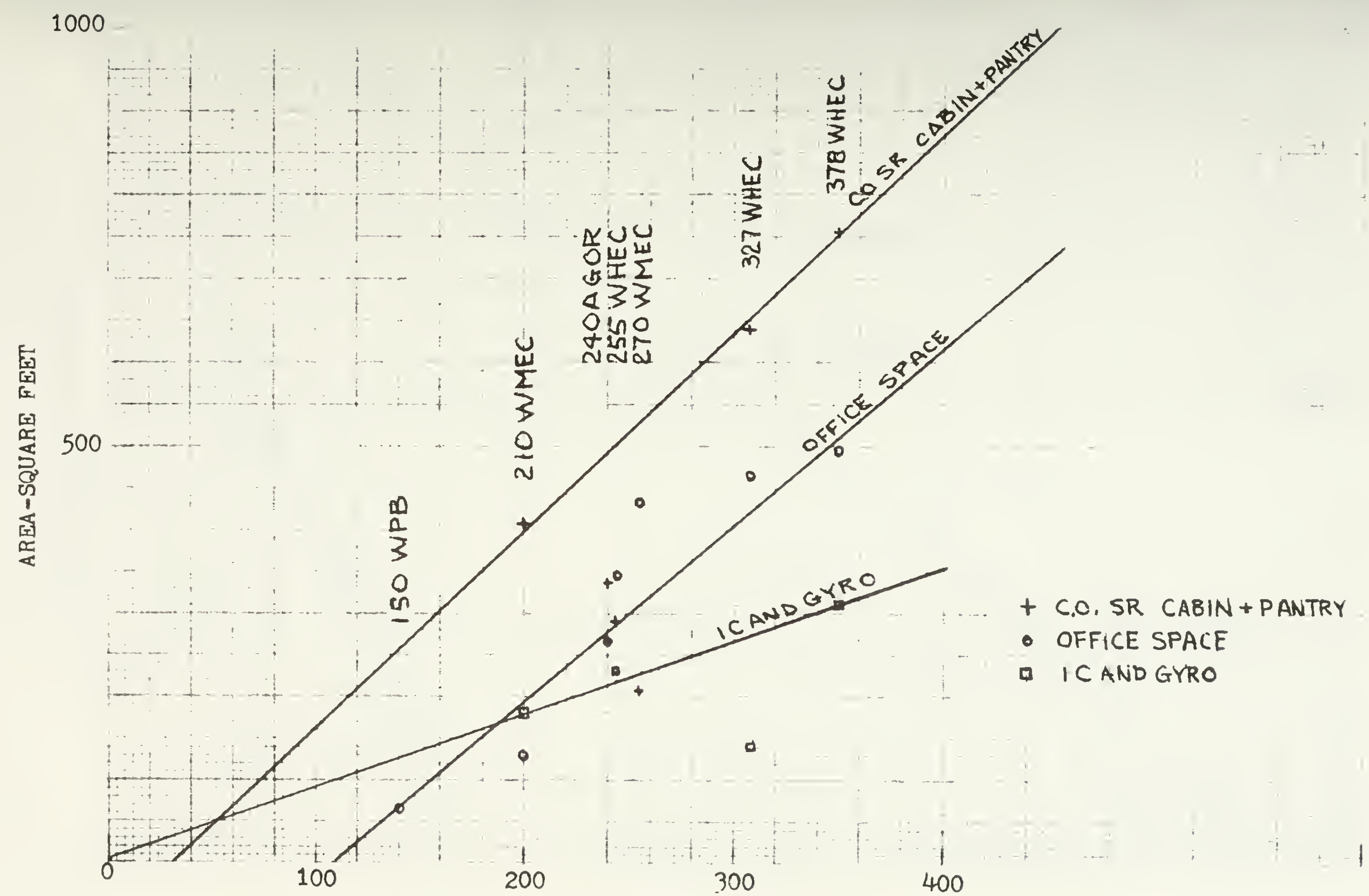
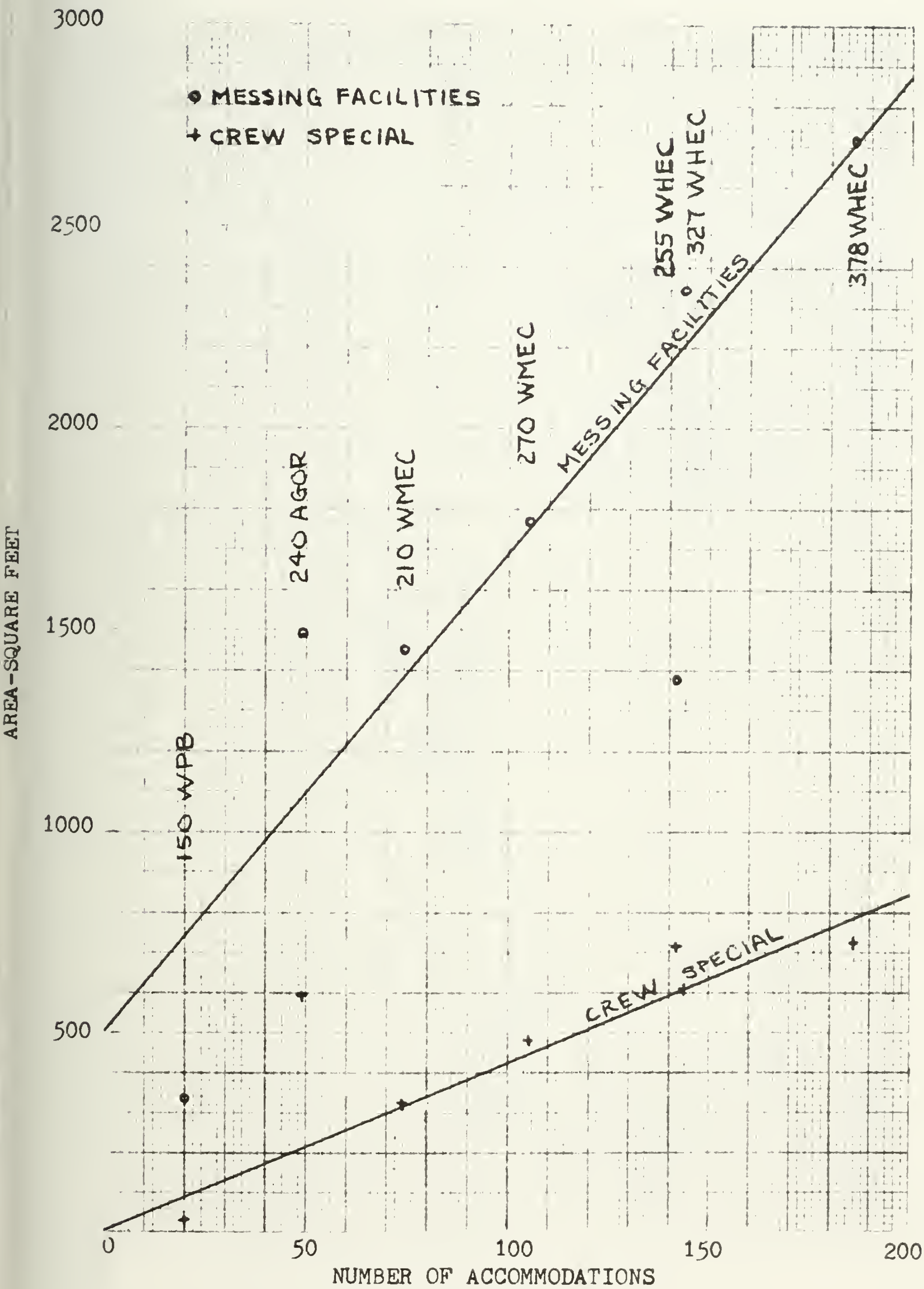


FIGURE 18: ARRANGEMENT AREAS

FIGURE 19: ARRANGEMENT AREAS



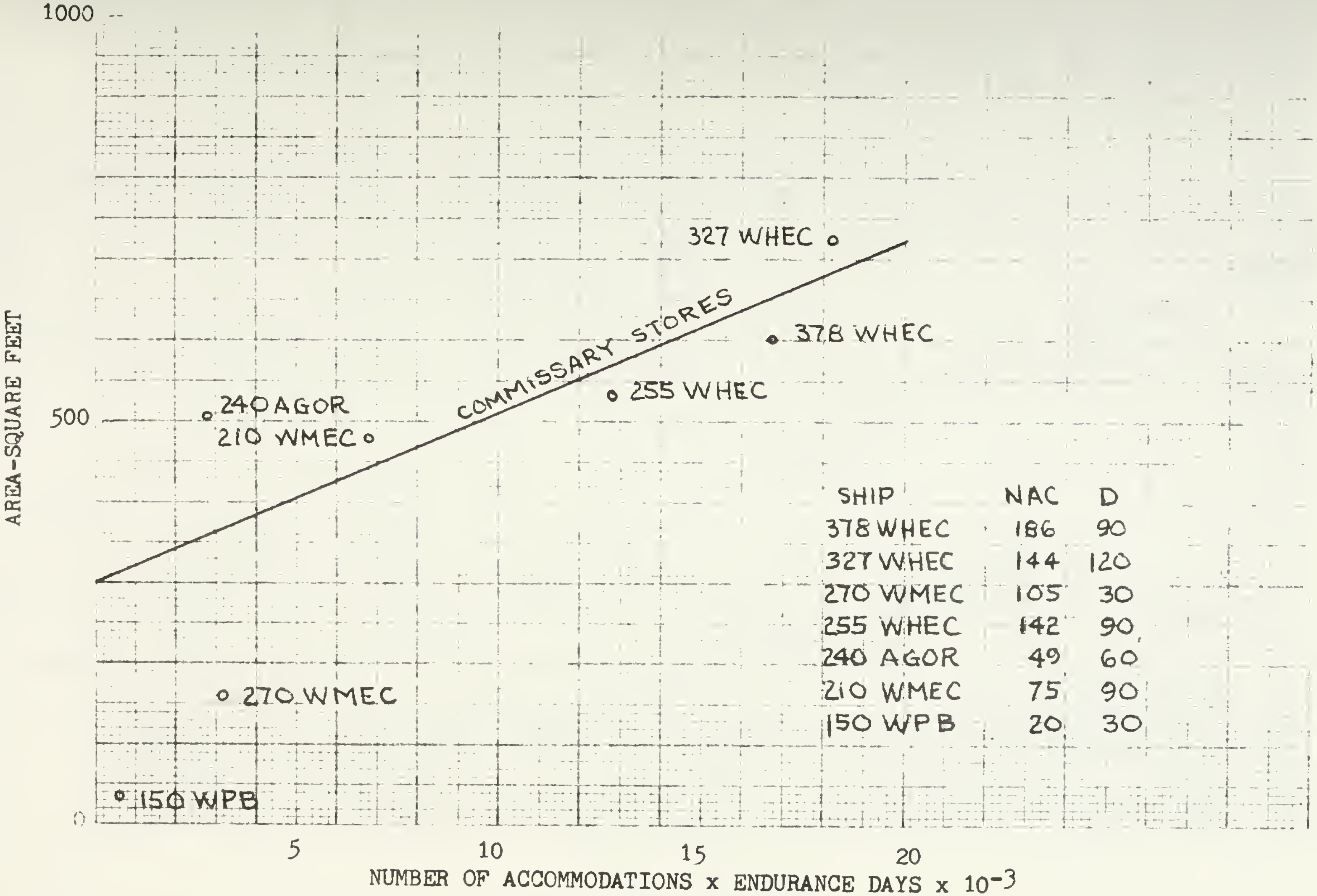


FIGURE 20: ARRANGEMENT AREAS

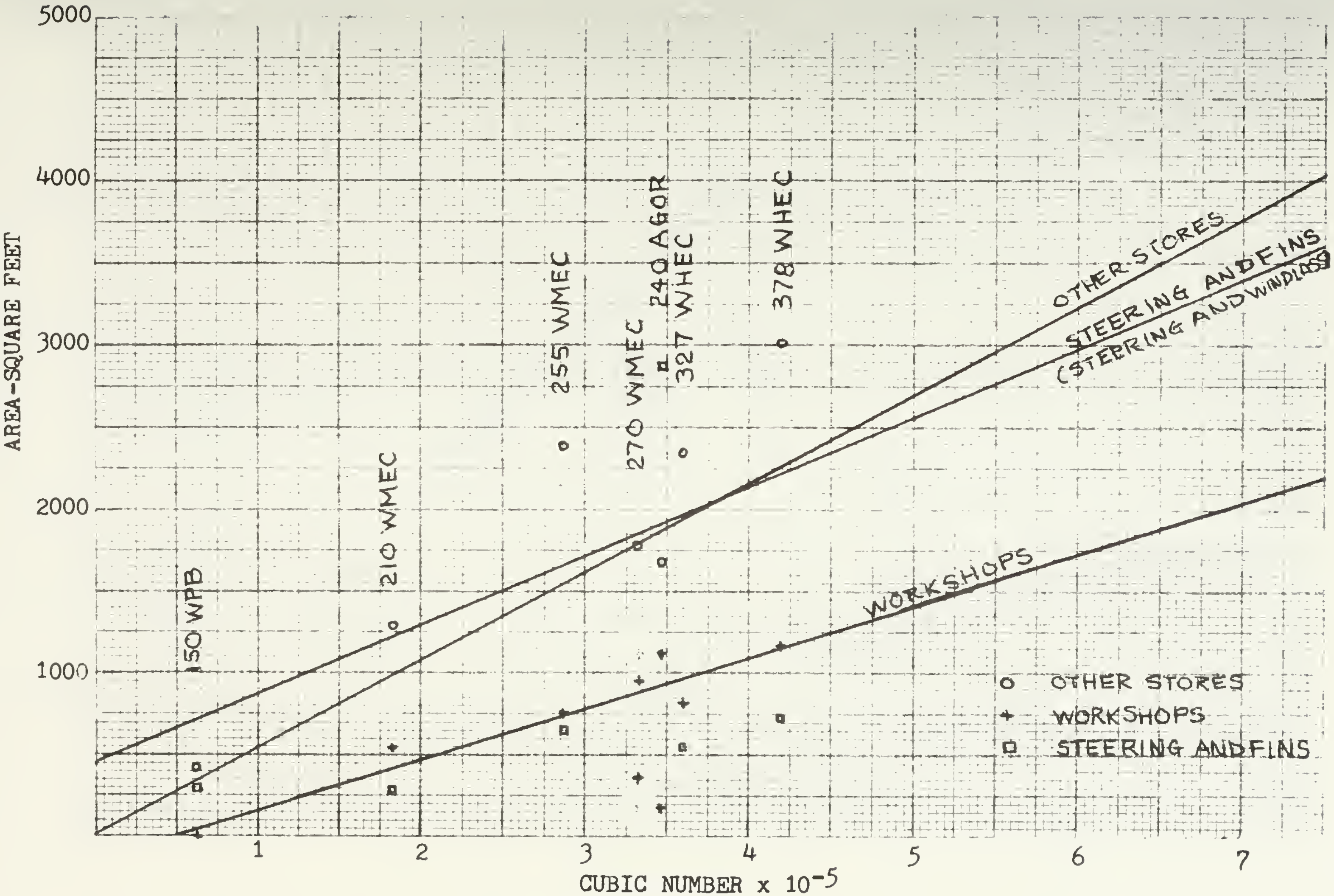


FIGURE 21: ARRANGEMENT AREAS

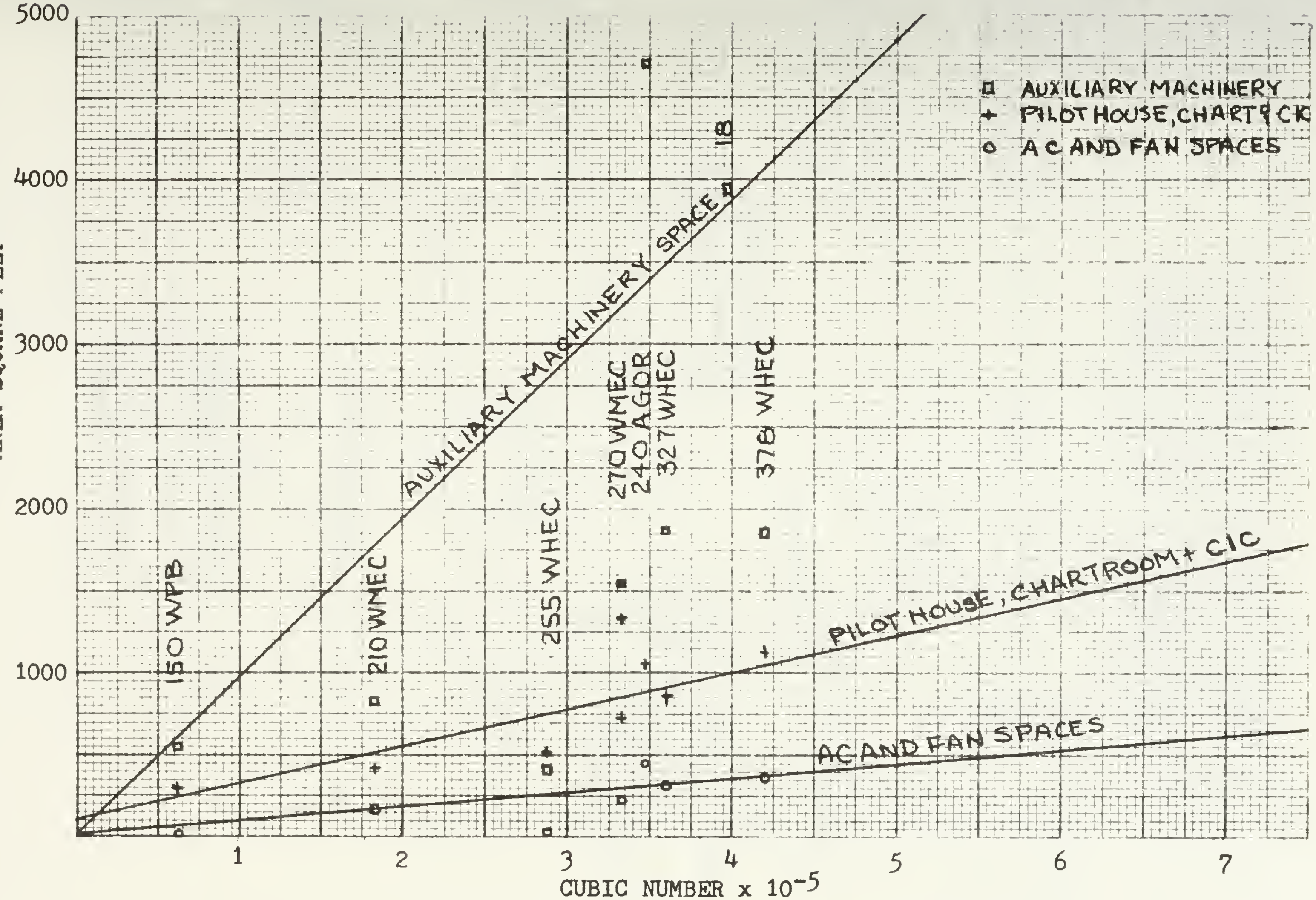


FIGURE 22: ARRANGEMENT AREAS

FIGURE 23a: VOLUME SUBROUTINE FLOW CHART

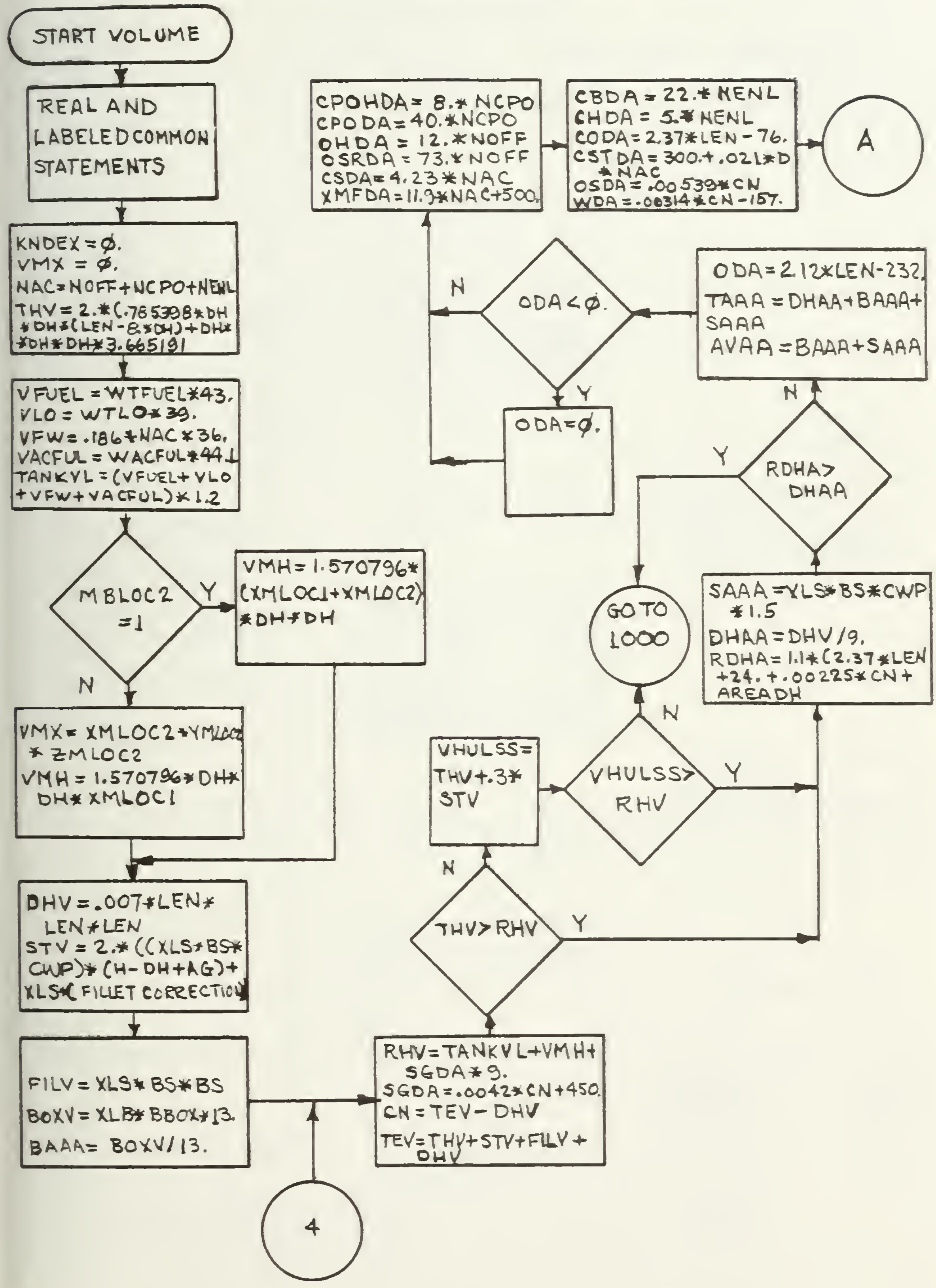
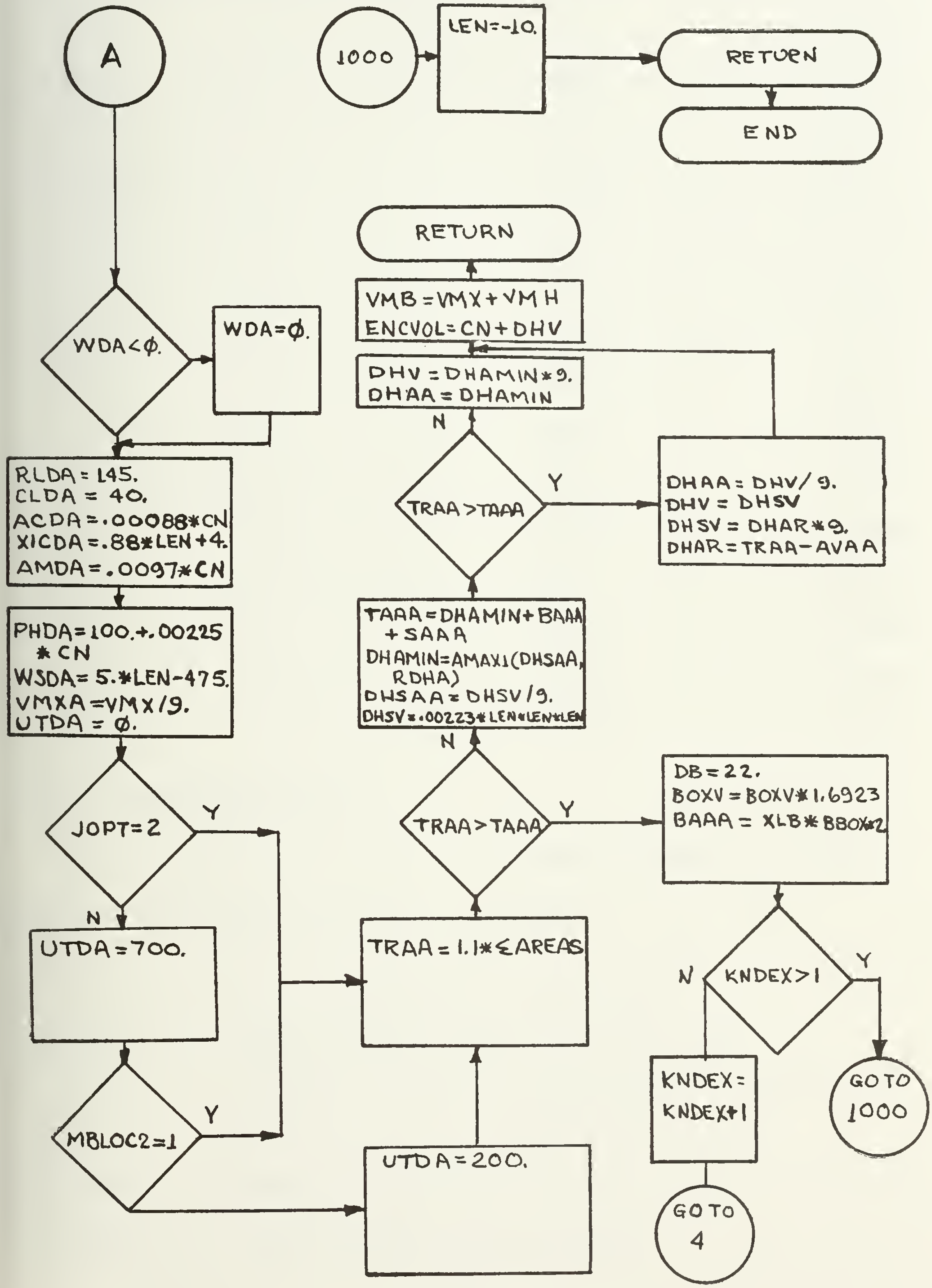


FIGURE 23b: VOLUME SUBROUTINE FLOW CHART-continued



6.9.5 Output List for Subroutine VOLUME

ACDA	LC(PP)	ODA	LC(PP)
AMDA	LC(PP)	OHDA	LC(PP)
AVAA	LC(PP)	OSDA	LC(PP)
CBDA	LC(PP)	OSRDA	LC(PP)
CHDA	LC(PP)	PHDA	LC(PP)
CLDA	LC(PP)	RLDA	LC(PP)
CN	LC(BB)	SGDA	LC(PP)
CODA	LC(PP)	TANKVL	LC(PP)
CPODA	LC(PP)	UTDA	LC(PP)
CPOHDA	LC(PP)	VMB	LC(PP)
CSDA	LC(PP)	VMXA	LC(PP)
CSTDA	LC(PP)	WDA	LC(PP)
DHAA	LC(PP)	WSDA	LC(PP)
DHV	LC(BB)	XICDA	LC(PP)
ENCVOL	LC(BB)	XMFDA	LC(PP)

6.9.6 Nomenclature List

The definition of all variables is the same as given in the MAIN program nomenclature except for the following:

ACDA	A/C & ventilation deck area, sq ft
AMDA	aux. machinery spaces deck area, sq ft
AVAA	available arrangements area in box and struts, sq ft
BAAA	available arrangements area in box, sq ft
BOXV	volume of box, cu ft
CBDA	crews berthing deck area, sq ft

CHDA	crew heads deck area, sq ft
CLDA	chain locker deck area, sq ft
CODA	C.O. S.R., Cabin & pantry deck area, sq ft
CPODA	CPO S.R. deck area, sq ft
CPOHDA	CPO heads deck area, sq ft
CSDA	crew special deck area, sq ft
CSTDA	commissary stores deck area, sq ft
D	stores endurance, days - ENDDAY in MAIN
DHAA	deckhouse arrangements area, sq ft
DHAMIN	minimum deckhouse area, sq ft
DHAR	deckhouse area required, sq ft
DHSAA	smallest deckhouse arrangements area, sq ft
DHSV	smallest deckhouse volume, cu ft
FILV	volume of strut - box fillets, cu ft
KNDEX	counter
NAC	number of accommodations
ODA	office deck area, sq ft
OHDA	officer heads deck area, sq ft
OSDA	other stores deck area, sq ft
OSRDA	officer staterooms deck area, sq ft
PHDA	pilothouse, chartroom & CIC deck area, sq ft
RDHA	area required to be in deckhouse, sq ft
RLDA	repair locker deck area, sq ft
RHV	required volume in hulls, cu ft
SAAA	available arrangements area in struts, sq ft
SGDA	steering gear & fins deck area, sq ft

STV	strut volume, cu ft
TAAA	total available arrangements area, sq ft
TANKVL	tankage volume, cu ft
TEV	total enclosed volume, cu ft
THV	total hull volume, cu ft
TRAA	total required arrangements area, sq ft
UTDA	uptake deck area in hull, sq ft
VACFUL	volume of aircraft fuel, cu ft
VFUEL	volume of ships fuel, cu ft
VFW	volume potable water, cu ft
VHULSS	volume of hulls and fraction of struts used for excess liquids, cu ft
VLO	volume of lub oil, cu ft
VMB	volume of machinery box, cu ft
VMH	volume of machinery in hulls, cu ft
VMX	volume of machinery in box, du ft
VMXA	deckarea of machinery spaces located in box, sq ft
WDA	workshops deck area, sq ft
WSDA	mooring station deck area, sq ft
XICDA	I. C. & gyro room deck area, sq ft
XMFDA	messing facilities deck area, sq ft

6.10 Subroutine WEIGHT

6.10.1 Purpose and Approach

This subroutine estimates the weight of the ship to the one digit level or better based on the available data and provides weight estimates for a balance between full load weight and displacement.

The weight groups estimated by this routine are broken down according to the NAVSHIPS Hull Group Weight Classification of 1965 shown in Appendix D. This classification is used by the Coast Guard. Several of the weight groups are not estimated by this routine. Groups 4 and 7, communication and control and armament, respectively are given as inputs to the model. Group 2 will not be estimated by the routine if the machinery weight is an input. The liquid load weights have been previously calculated in subroutine LIQ. The remaining groups, 1, 2, 3, 5, 6 and loads are estimated in this routine.

Group 1 weights for the SWATH configuration are significantly different from the conventional ship. SWATH group 1 weight data was compiled and parametric studies used to determine the best combination of parameters to use to estimate weight conveniently. Data from SWATH machinery weight estimates, empirical weight estimation equations for group 2, data from other ship types and rough estimates of group 2 weights were combined to generate simple relations for group 2 weights. SWATH data and data from Coast Guard Cutters given by Goodwin were used to form relationships for groups 3, 5 and 6. The load assumptions used are the same as those used by Goodwin.

6.10.2 <u>Input List for Subroutine WEIGHT</u>

CN	LC(BB)	ELKW	LC(DD)
D	LC(AA)	ENCVOL	LC(BB)
DB	LC(JJ)	JOPT	LC(CC)
DBMAR	LC(WW)	LEN	LC(BB)
DHV	LC(BB)	MOPT	LC(CC)

MTYPE . . . . LC(CC)	WCARGO . . . . LC(LL)
MBLOC2 . . . . LC(JJ)	WTAC . . . . LC(LL)
NCPO . . . . LC(AA)	WTAMMO . . . . LC(LL)
NENL . . . . LC(AA)	WTFUEL . . . . LC(LL)
NOFF . . . . LC(AA)	WTG2 (JOPT=2 only). LC(WW)
SHPE . . . . LC(CC)	WTG4 . . . . LC(WW)
SHPM . . . . LC(CC)	WTG7 . . . . LC(WW)
WACFUL . . . . LC(LL)	WTLO . . . . LC(LL)

6.10.3 Program Development

The basic approach of a weight estimating routine is to estimate the weight of each weight group in turn as a function of the variables which affect that weight group, to estimate the loads based on the crew size and operational requirements and to sum the group weights multiplied by a margin with the load weights to determine the full load weight. This is exactly what is done in this routine. Determining the proper variables and functional relationships to use in making the estimator may be difficult. Group 1 is estimated here as a function of the number of decks in the box, the material and ship dimensions. Group 2 estimating relationships are based on the location and type of machinery and the horsepower. Group 3 estimates are based on the installed generator size and the volume of the ship. Group 5 and 6 estimates are based on the enclosed volume of the ship. The following paragraphs indicate the methods of development of these estimating relationships.

Group 1 weight estimation for a SWATH is somewhat more complex than for a conventional ship due to the structural problem of connecting the two hulls through struts and a cross structure. Complex structural

analysis would be necessary to find the exact requirements for scantlings and weight. A structural analysis for each feasibility study is too complex and time consuming to be an acceptable solution. Therefore a method for estimating weights based on existing SWATH studies, some of which have had structural analysis or detailed structural weight estimates, was desired. The dimensions of the ship, the enclosed volume, the displacement, the number of decks and struts and the material used are all variables affecting the weight. Plots of group 1 weights versus length or cubic number as functions of number of decks and material are not suitable estimators. However, group 1 weights is strongly affected by the total area of structure in the ship as indicated by Arrone[20]. Approximate values of the surface of structure enclosing the ship were computed. The structural density of the ships were computed. A vehicle density versus group 1 weight fraction curve was plotted with cross curves of material and number of decks alternatives (Steel-one deck, Aluminum-two decks, etc.) and of structural surface area. Linear trend lines were plotted for four alternatives: two deck-steel, two deck-aluminum, one deck-steel and one deck-aluminum. Figure 24 shows these curves. These expressions are of the form:

Weight 1/Displacement = A(Displacement/Enclosed Volume) + B

To confirm this type of formulation equations for the displacement, volume and surface area for a hypothetical SWATH based on average dimensions were developed. For a two deck box these equations are:

$$\text{Displacement} = .00015707*\text{Length}^3 \text{ Tons}$$

$$\text{Structural Surface Area} = 920 + 1.18777*\text{Length}^2 + 121.01786*\text{Length}$$

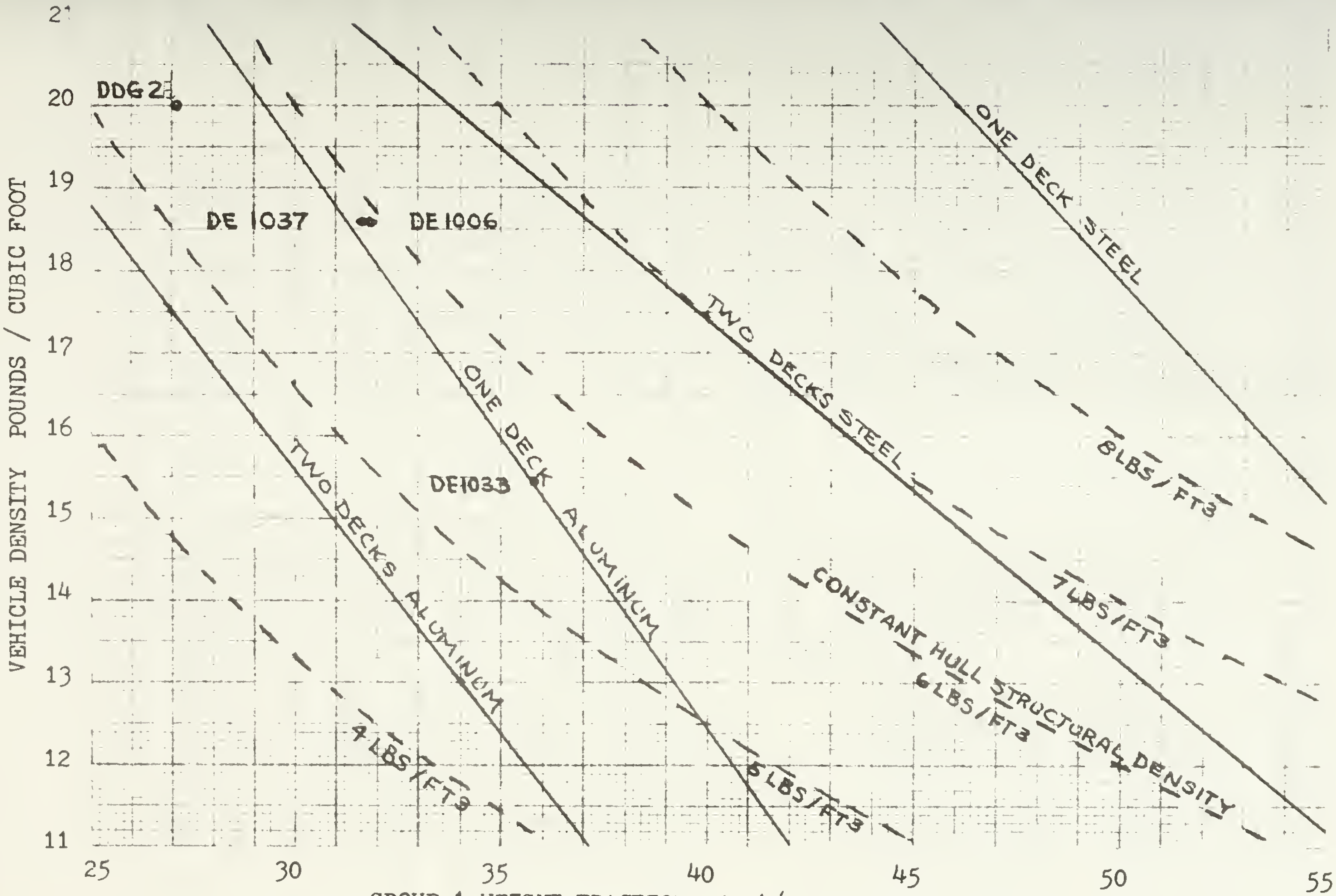


FIGURE 24: VEHICLE DENSITY VERSUS WEIGHT GROUP 1 WEIGHT FRACTION

$$\text{Enclosed Volume} = 165.048*\text{Length} + 6.196155*\text{Length}^2 + .0054973*\text{Length}^3$$

For a one deck box the surface area and volume equations are as follows:

$$\text{Structural Surface Area} = 560 + 102.01346*\text{Length} + 1.18777*\text{Length}^2$$

$$\text{Enclosed Volume} = 100.464*\text{Length} + 3.935715*\text{Length}^2 + .0054973*\text{Length}^3$$

Based on scantling data from early Navy structural studies(8), equations were derived for the average value of plate weight for the structure as a function of the number of decks, length and beam of the vessel and the material selection. These equations are of the form:

$$\text{Average Plate Weight} = c_1*\text{Length}*\text{Beam} + c_2$$

The applicability of these equations must be limited to a range of values of the length times beam to remain consistent with the input data. By combining the equations for the average plate weight and for structural surface area, the weights of structure for hypothetical SWATH ships can be estimated. These data are then plotted on a vehicle density versus weight group 1 weight fraction curve and the results compared with the vehicle density curves previously prepared. The hypothetical values check well with the input data. This is not unexpected as the same data base was used for both calculation approaches, but it shows internal consistency. The linear estimating relationships derived estimate well in the mid-range of the length values accepted by the program, but over-estimate for small ships.

Two suggestions for estimating group 1 weights indicated in reference (3) were also evaluated. The first of these methods was a plot of weight fraction versus length. This estimator was discarded because it did not treat a sufficient number of assumed primary variables such as materials, decks and geometry. The second method evaluated was a plot of weight fraction versus displacement as functions of the material selection. Mean lines drawn through this type of data for high tensile steel SWATHs results in the following equation:

WT1/Displacement≈40- .002*Displacement, percent

For aluminum construction with no allowances for structural fire protection the corresponding equation is:

WT1/Displacement = 27.29 - .001225*Displacement, percent

This approach leads to an error of more than twenty percent in estimating ships in the data base. Because of this error and its lack of attention to the primary dimension variables, this method of estimating group 1 weight was also discarded. The linear equations developed using the comparison of the data base and the hypothetical ship were used in estimating group 1 weights in this model. These relationships are shown in Figure 24. The equations developed from this figure and used in the model's calculation are:

WT1 = .82285*DPTRY-54.40049*DPTRY*DPTRY/CN for two deck steel SWATHS

WT1 = .542222*DPTRY-34.84444*DPTRY*DPTRY/CN for two deck aluminum SWATHS

WT1 = .83335*DPTRY-41.8151*DPTRY*DPTRY/CN for one deck steel SWATHS

WT1 = .577857*DPTRY-32.000039*DPTRY*DPTRY/CN for one deck aluminum SWATHS

where DPTRY is the displacement in tons and CN is the enclosed volume of the ship up to the main deck. These relationships include a 15 percent margin. Figure 24 also shows conventional destroyer data and lines of constant structural density for comparison.

Weight group 111 is estimated as a function of the enclosed volume of the deckhouse. The destroyer model DD07 uses the relationship WT111 = .00085*DHV. SWATH deckhouses are more box-like than those of destroyers and can make more efficient use of structure because of this shape. SWATH deckhouse weights are better estimated by:

WT111 = .000353*DHV

Estimates of machinery weight, Group 2, are made based on estimates of existing plants and previous ship synthesis model results. The entire weight group is estimated by one equation because the data inputs are not detailed enough to permit further breakdown. Conventional Diesel plants are estimated using data presented by Goodwin[11]. Gas turbine plants are estimated from SWATH studies (8) and confirmed using a method developed by Reed[23] and suitably modified for SWATHs. Electric propulsion component weights are estimated from data in Harrington[24] and limited SWATH data is used for comparison. Only one data point is available for gas turbine electric plants. The estimating relationship is derived by estimating the component total weights over a range of horsepower and translating the resulting mean line until it passes

hrough the data point. Although the trends resulting from these estimators appear to be correct, the data base is limited. The estimating relationships are shown in Figure 25.

WTG2 = .03754*SHPM**.925 for Diesel propulsion

WTG2 = .1109828*SHPM**.86 for Diesel-electric propulsion

WTG2 = .339053*SHPM**.634 for gas turbine propulsion

WTG2 = .4777*SHPM**.692 for gas turbine-electric propulsion

There are two cases where the prime mover is located in the hull and power must be transmitted to the propulsor through a gear system in the struts. For these cases the group 2 weight is incremented to account for this extra transmission weight.

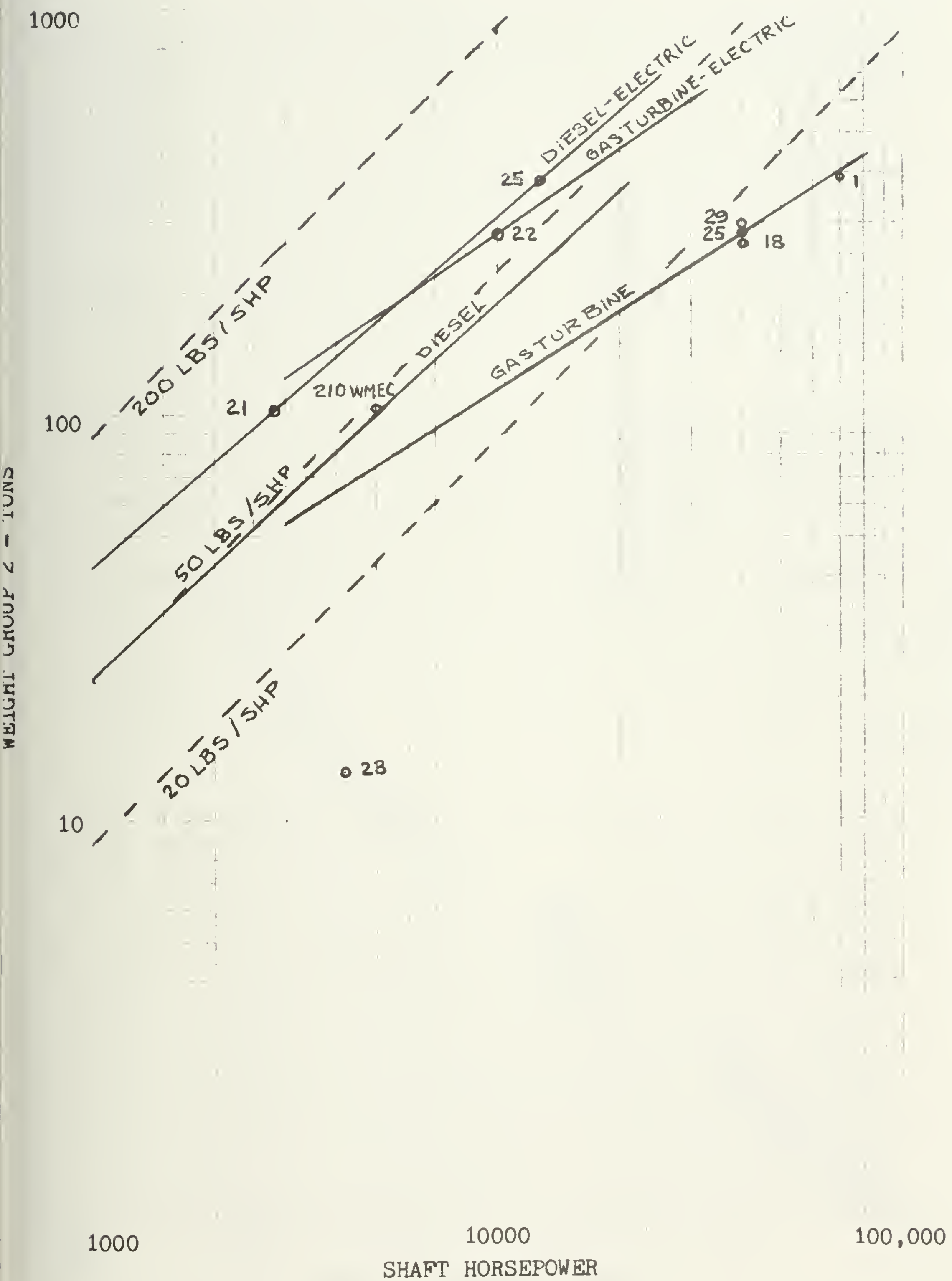
WTG2 = WTG2 + .001*SHPM-2.033, tons

Goodwin's estimating relationships were used in this model for the electric power generation and power distribution switchboards classifications. Figure 26 shows the estimating relationship for power generation. The remainder of group 3 weight was estimated as a function of the enclosed volume. The total weight of this group is small and any inaccuracies in the estimates will have a small impact on the overall design.

WT3R = .0001534*ENCVOL

Group 5 weight is estimated as a function of the enclosed volume. SWATH data indicate that the group 5 weight is of approximately the same functional relationship as the data compiled for conventional ships and

FIGURE 25: WEIGHT GROUP 2 VERSUS SHAFT HORSEPOWER



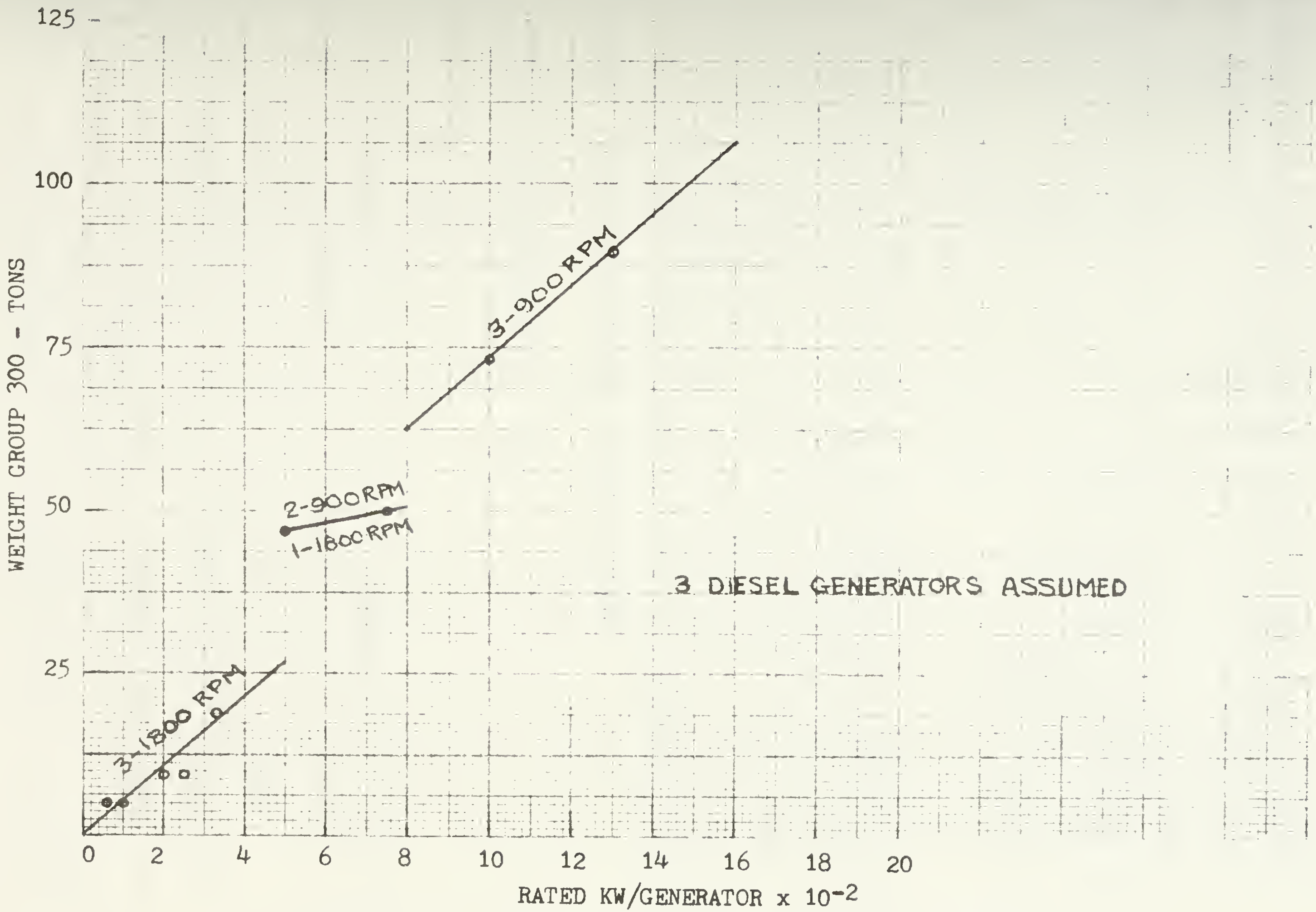


FIGURE 26: WEIGHT GROUP 300 VERSUS RATED KW/GENERATOR

given in DD07 and Goodwin but with a substantial weight reduction. Volume should be the most important variable for auxiliary weight but it is felt that the increase in weight should decrease with increasing volume and boxiness. The following equation for estimating group 5 weight is of the same form as that used previously for conventional ships but the coefficients have been reduced to agree with SWATH data.

WTG5 = .000023072*ENCVOL*ENCVOL + .00065456*ENCVOL

This relationship is shown in Figure 27.

Group 6 weight is also estimated as a function of enclosed volume based on SWATH data. No accounting has been made for fire insulation of aluminum hulls nor has an allowance been added for excess boats. One surfboat can be assumed for crews up to 25 and two such boats for larger crews. If more small boats are to be carried, they should be added as cargo items. The relationship for group 6 weight,

WTG6 = .05318*ENCVOL**.6266

is shown in Figure 28.

The light ship weight is determined by adding the five weight groups which have been calculated and the two, groups 4 and 7, which have been input and multiplying the sum by the design and builders margin.

The full load displacement is calculated by adding the light ship weight and the loads. The loads consist of the liquid leads calculated by Subroutine LIQ, the cargo, ammunition, aircraft and aircraft fuel inputs, crew, personal effects and stores. The crew is assumed to weigh 165

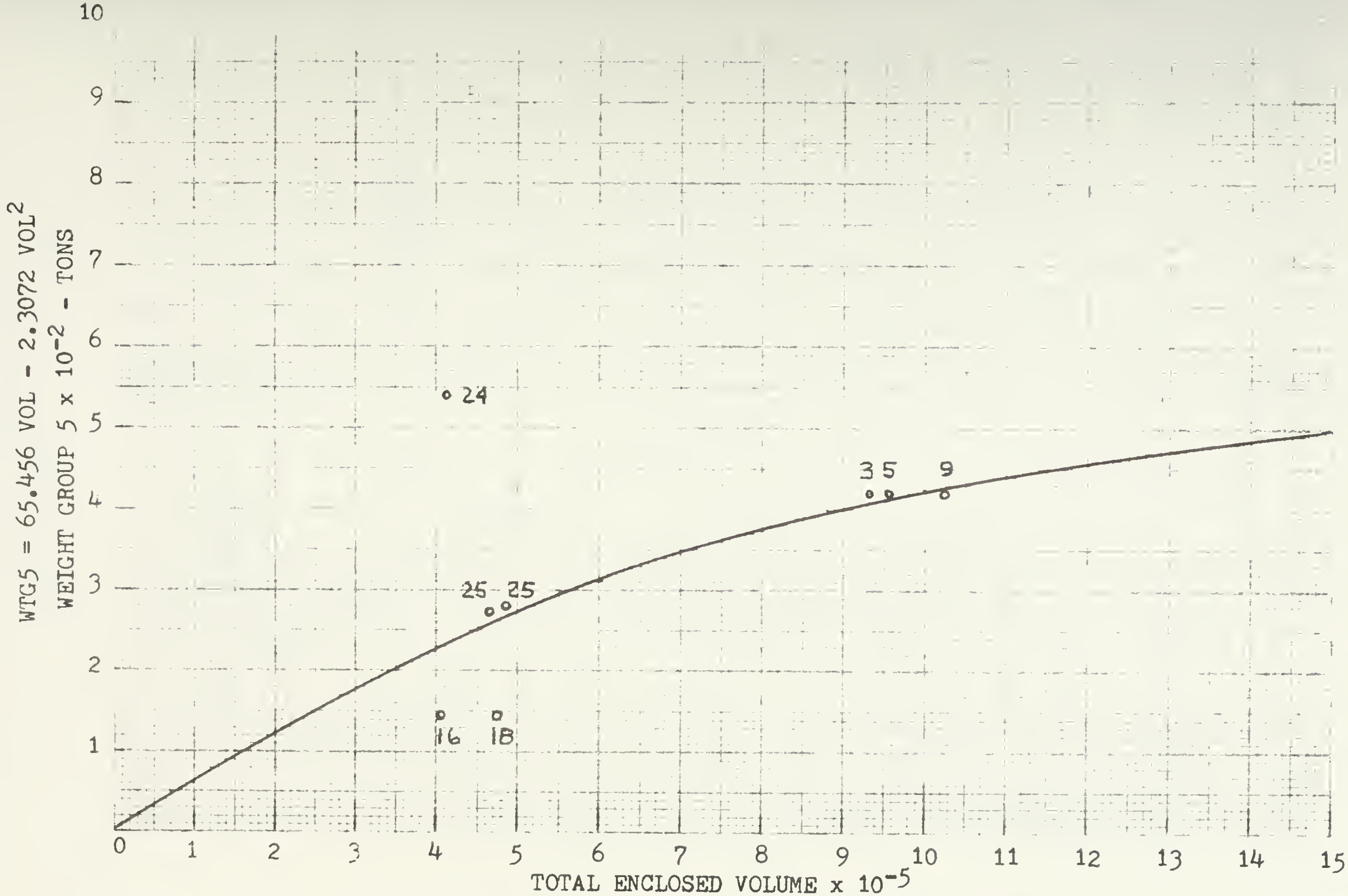


FIGURE 27: WEIGHT GROUP 5 VERSUS ENCLOSED VOLUME

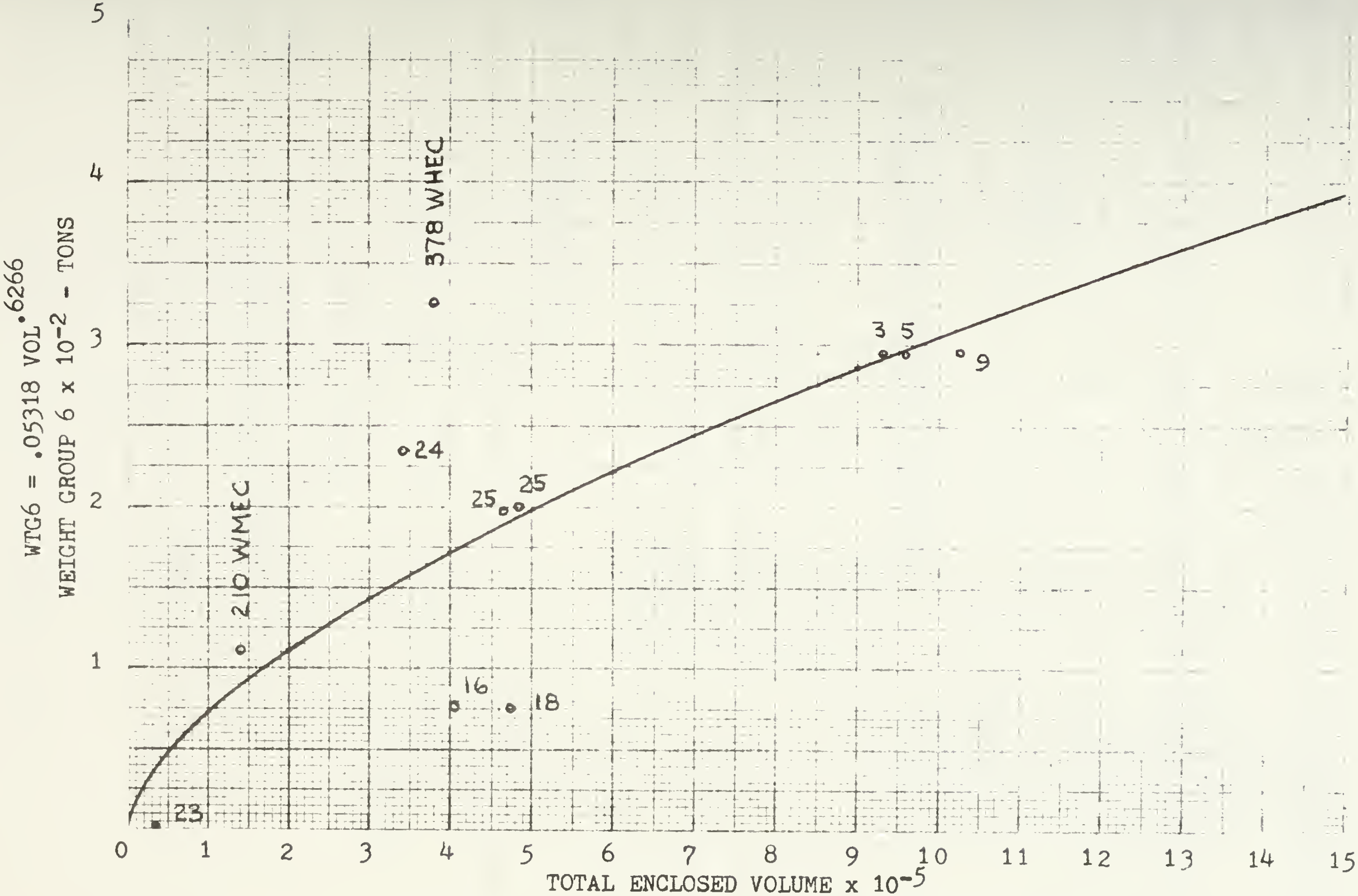


FIGURE 28: WEIGHT GROUP 6 VERSUS ENCLOSED VOLUME

pounds per man and personal effects, 235 pounds per officer, 165 pounds per chief petty officer and 65 pounds per enlisted man. The weight of stores is a function of the crew size and the required endurance.

Weight of Stores = (.0222+.00202*D)*NAC + .00135*D*NAC

The weight of potable water is again calculated as 50 gallons per man or 0.186*NAC, tons.

6.10.4 Flow Chart

A flow chart for Subroutine WEIGHT is shown in Figure 29.

6.10.5 Output List for Subroutine WEIGHT

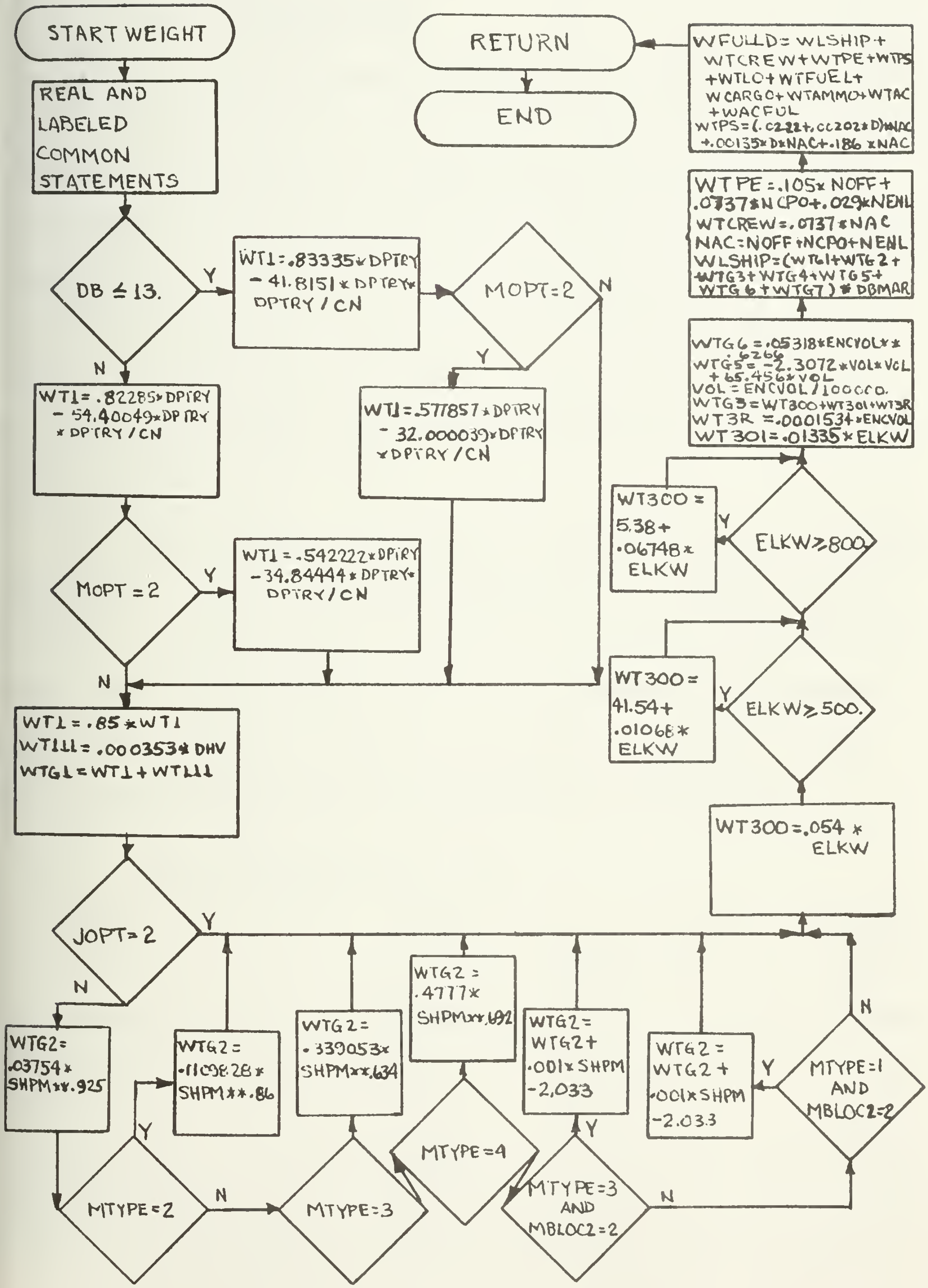
WFULLD	LC(WW)	WTG3	LC(WW)
WLSHIP	LC(WW)	WTG5	LC(WW)
WTCREW	LC(LL)	WTG6	LC(WW)
WTG1	LC(WW)	WTPE	LC(LL)
WTG2 (JOPT=1 only)	LC(WW)	WTPS	LC(LL)

6.10.6 Nomenclature List

The definitions of all variables used in this routine are the same as those used in the MAIN program with the following exceptions:

D	endurance days for dry provisions - same as ENDDAY in MAIN
NAC	number of accommodations
VOL	enclosed volume x 10^{-5}
WT111	weight of group 111, tons
WT300	weight of group 300, tons
WT301	weight of group 301, tons
WT3R	weight of remainder of group 3, tons

FIGURE 29: WEIGHT SUBROUTINE FLOW CHART



6.11 Subroutine VCG

6.11.1 Purpose and Approach

Subroutine VCG estimates the location of the vertical center of gravity of the ship in the full load condition. Data from weight estimates of previous SWATH designs are used to determine feasible locations of the vertical centers of gravity of the various weight groups and load items. These data are tabulated as the ratio of the vertical center of gravity location to the depth to the top of the box for each SWATH ship. The routine selects the appropriate value of VCG/DT for use in computing the total vertical moment of the ship and the resultant vertical center of gravity location.

The values assigned to the VCG/DT ratio by the routine are feasible values only. The free surface correction term may be used to effect a variation of the center of gravity location as it is subtracted from the KG value. Additional variation in KG values are possible with the SWATH configuration because the transverse stability is controlled to a large extent by the hull separation rather than the exact value of KG.

6.11.2 Input List for Subroutine VCG

ACCG	LC(EE)	D	LC(AA)
ACWT	LC(EE)	DBMAR	LC(WW)
AMOCG	LC(EE)	DH	LC(GG)
AMOWT	LC(EE)	GR4CG	LC(EE)
CACFUL	LC(HH)	GR4WT	LC(EE)
CARGOC	LC(EE)	GR7CG	LC(EE)
CARGOW	LC(EE)	GR7WT	LC(EE)

MBLOC2	LC(JJ)	WTG1	LC(WW)
MTYPE	LC(CC)	WTG2	LC(WW)
NOARM	LC(FF)	WTG3	LC(WW)
NOELT	LC(FF)	WTG4	LC(WW)
WCARGO	LC(LL)	WTG5	LC(WW)
WFULLD	LC(WW)	WTG6	LC(WW)
WLSHIP	LC(WW)	WTG7	LC(WW)
WTAMMO	LC(LL)	WTLO	LC(LL)
WTCREW	LC(LL)	WTPE	LC(LL)
WTFUEL	LC(LL)	WTPS	LC(LL)
		WACFUL	LC(LL)

6.11.3 Program Development

Data on the vertical center of gravity location for various weight groups and load items are tabulated in Table VII. The machinery type, machinery location, number of decks and the material selected influence the values of VCG/DT selected. The ASSUMED column of the table indicates the condition codes for the various assumptions made and the assumed values of VCG/DT used in the model. This routine calculates the depth to the main deck of the SWATH using the geometry previously determined and an assumed deck height of 9 feet. The center of gravity value for group 1 is determined as a function of the material option, number of decks and the depth. The center of gravity value for group 2 is determined as a function of the machinery type, the location of the prime mover, the shaft horsepower and the total depth. Groups 3, 5 and 6 centers of gravity locations are estimated as a function of the number of decks. Groups 4 and 7 centers are input values as are centers for aircraft fuel, cargo, aircraft and ammunition. The values of VCG/D

or groups 4 and 7 and payloads given in the table may be used for initial stimates of input values. The vertical moments for these items are alculated in two DO loops in the routine and the vertical centers are etermined. The light ship vertical center is calculated by summing the eights times the appropriate center of gravity times the margin divided y the light ship weight. Next the centers of gravity of load items are stimated. Liquids are generally assumed to be centered at the centers f the hulls. Crew and effects and stores are assumed to be in the box. The total vertical moment due to loads is computed. The sum of the light hip moment and the loads moment divided by the full load displacement esults in the vertical center of gravity location which is returned to the ECUTE subroutine.

6.11.4 Flow Chart

The flow chart for the VCG subroutine is shown in Figure 30.

6.11.5 Output List for Subroutine VCG

CCARGO	LC(OO)	CGG3	LC(OO)
CFULD	SCDA	CGG4	LC(OO)
CFULLD	LC(OO)	CGG5	LC(OO)
CGAC	LC(HH)	CGG6	LC(OO)
CGAMMO	LC(HH)	CGG7	LC(OO)
CGCREW	LC(HH)	CGLO	LC(HH)
CGFUEL	LC(HH)	CGPE	LC(HH)
CGG1	LC(OO)	CGPS	LC(HH)
CGG2	LC(OO)	CLSHIP	LC(OO)

VERTICAL CENTER OF GRAVITY DATA

SHIP	23	24	24 MOD	25	25	ASSUMED MTYPE/ MBLOC2	ASSUMED DECKS	ASSUMED MOPT	ASSUMED VCG/ DT
MTYPE/MBLOC2	3/2	3/1	3/1	3/1	2/2				
DECKS	1	1	1	2	2				
MOPT	1	1	1	1	1				
WEIGHTS:									
GROUP 1	.563	.604	.582	.605	.606		1	1	.58
							1	2	.57
							2	-	.605
GROUP 111	.978	1.220		1.125	1.124		-	-	-
GROUP 2	.403	.227	.223	.234	.388	1/-			.15
						2/2			.39
						3/2			.40
						3/1			.22
						4/2			.43
GROUP 3	.859	.916	.832	.781	.783				.869
									.782
GROUP 4		1.00		1.00					
GROUP 5	.319	.669	.669	.781	.783		1		.67
							2		.78
GROUP 6	.248	.879	.879	.771	.773		1		.88
							2		.77
GROUP 7		1.051		1.055	1.054				
CREW		.89		.828	.829				.89
PROVISIONS		.89		.828	.829				.85
GENERAL STORES		.89		.828	.829				.83
AMMUNITION		.89		.828	.829				
FUEL	.117	.127		.120	.122				
AIRCRAFT					1.062				
AIRCRAFT FUEL				.109	.109				
MARGIN	.502	.848	.615	.859	.860				
FULL LOAD	.500	.588	.616	.624	.624				

FIGURE 30a: VCG SUBROUTINE FLOW CHART

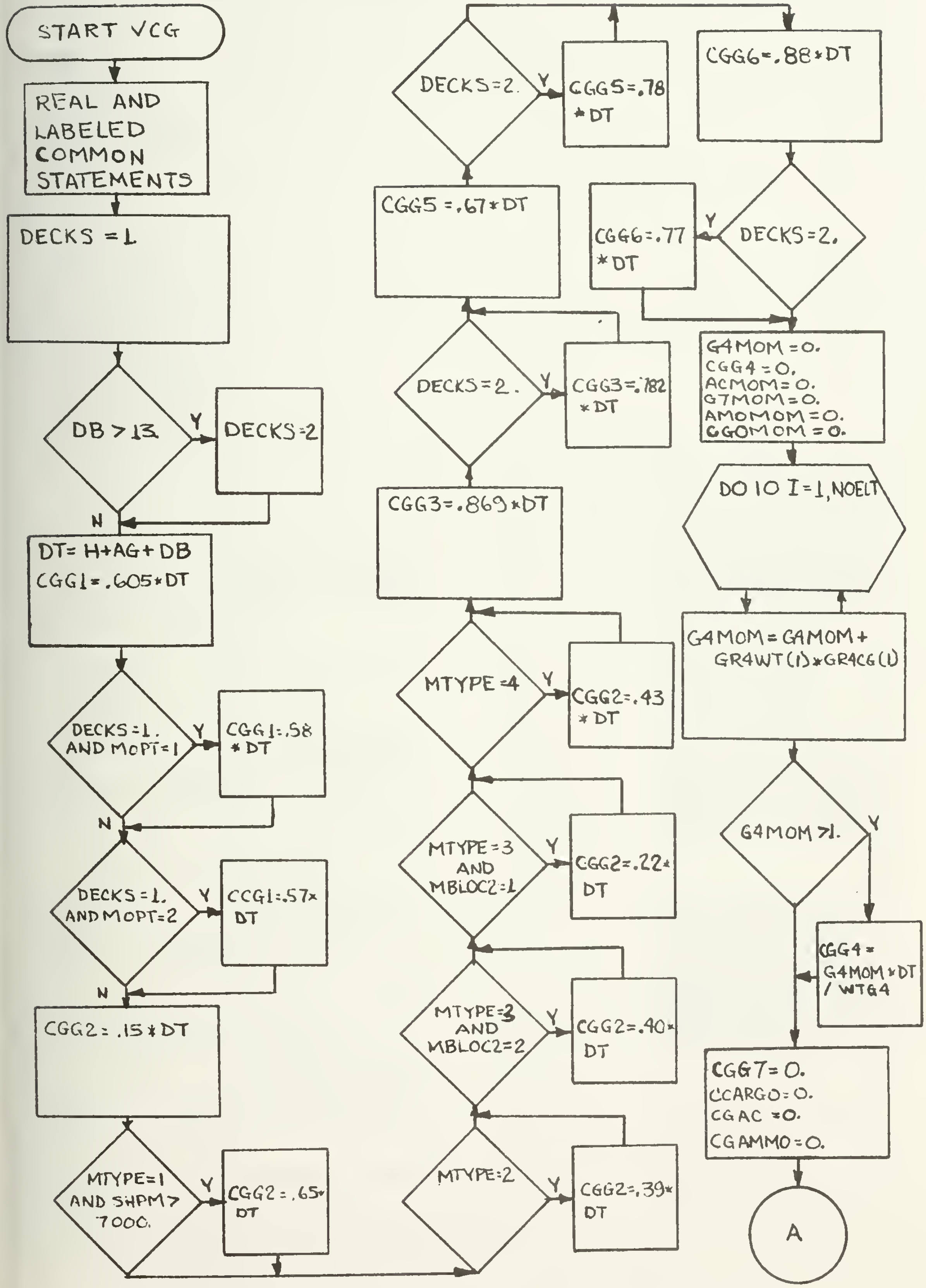
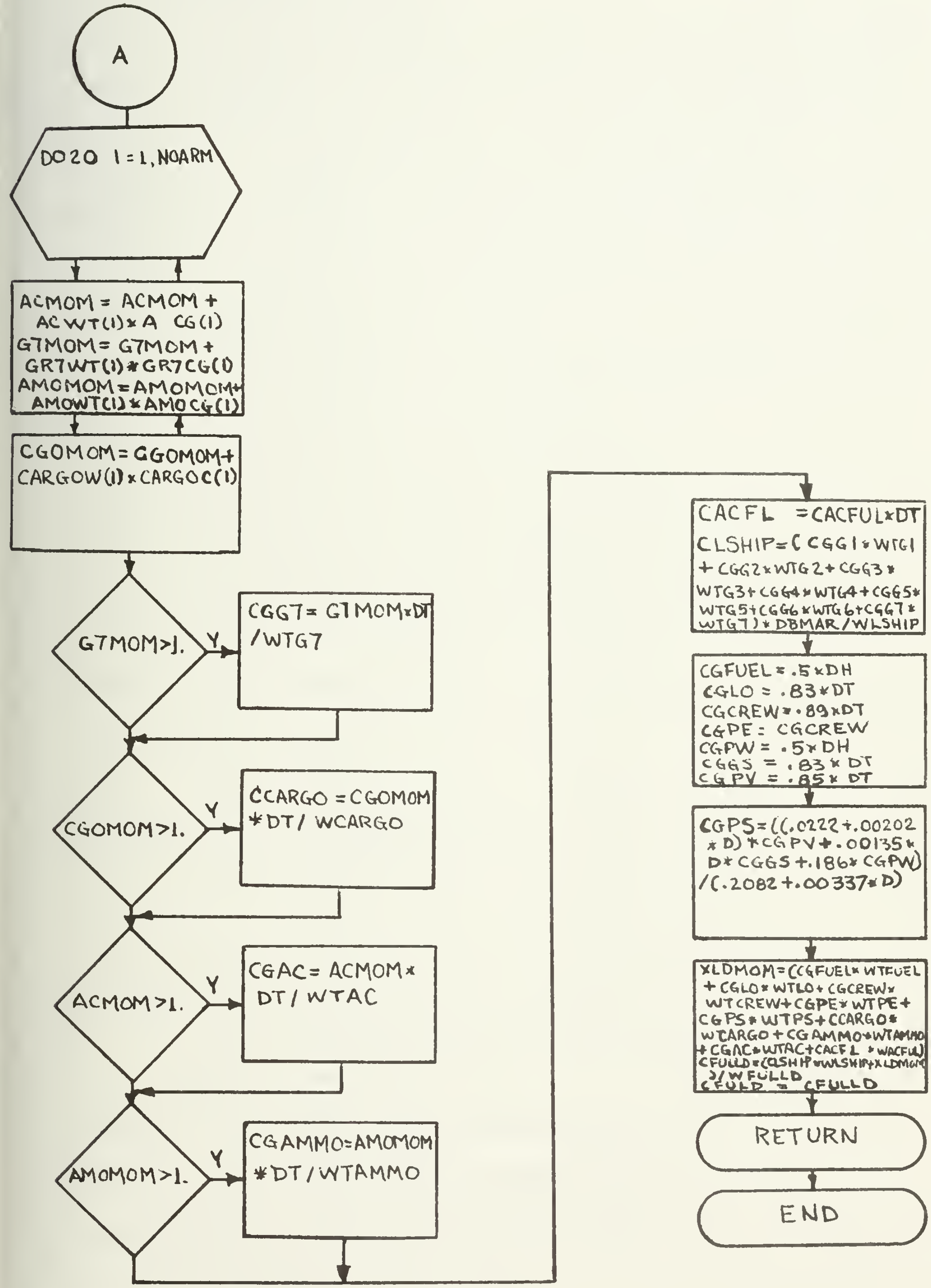


FIGURE 30b: VCG SUBROUTINE FLOW CHART-continued



6.11.6 Nomenclature List

The definitions of all variables used in this routine are the same as those used in the MAIN program with the following exceptions:

ACMOM	total vertical aircraft moment, tons
AMOMOM	total vertical ammunition moment, tons
CACFL	vertical center aircraft fuel, ft
CFULD	same as CFULLD
CFULLD	vertical center of ship at full load, ft
CGG1	vertical center of group 1, ft
CGG2	vertical center of group 2, ft
CGG3	vertical center of group 3, ft
CGG4	vertical center of group 4, ft
CGG5	vertical center of group 5, ft
CGG6	vertical center of group 6, ft
CGG7	vertical center of group 7, ft
CGGS	vertical center of general stores, ft
CGOMOM	vertical moment of cargo, tons
CGPV	vertical center of provisions, ft
CGPW	vertical center of potable water, ft
CLSHIP	vertical center of light ship, ft
D	endurance days for dry provisions - ENDDAY in MAIN
G4MOM	total group 4 moment, tons
G7MOM	total group 7 moment, tons
XLDMOM	total load moment, ton-ft

6.12 Subroutine COST

6.12.1 Purpose and Approach

This subroutine calculates the lead ship acquisition cost based on the seven light ship weight groups. The method was developed by Coast Guard Naval Engineering personnel (Flanagan's Method), used in graphical format and later in a computer routine for estimating ship acquisiton costs and programmed by Goodwin in the cutter model. This routine makes minor modifications to Goodwin's COST to make it applicable to the SWATH and provides several new estimating relationships which will be described below.

The routine uses materials cost equations developed from 1959 price data and thus require a correction factor to correct the prices in which the ship will be built. These cost indices are shown in Figure 31 and are based on Bureau of Labor Statistics data for a product representative of a weight group.

The labor rate for all weight groups is assumed to be the same and is input as an average labor rate in dollars per hour in the year in which the ship will be built. Bureau of Labor Statistics data for wage rates of shipyard workers is supplied as Figure 32. As there is wide regional variation of wage rates, the values extrapolated from the figure can only be considered averages.

Using the weight, cost index and labor rate data the routine calculates the materials, labor and miscellaneous costs of the ship and returns a cost breakdown and total cost figures to storage for printing as output.

FIGURE 31: COST INDICES VERSUS TIME

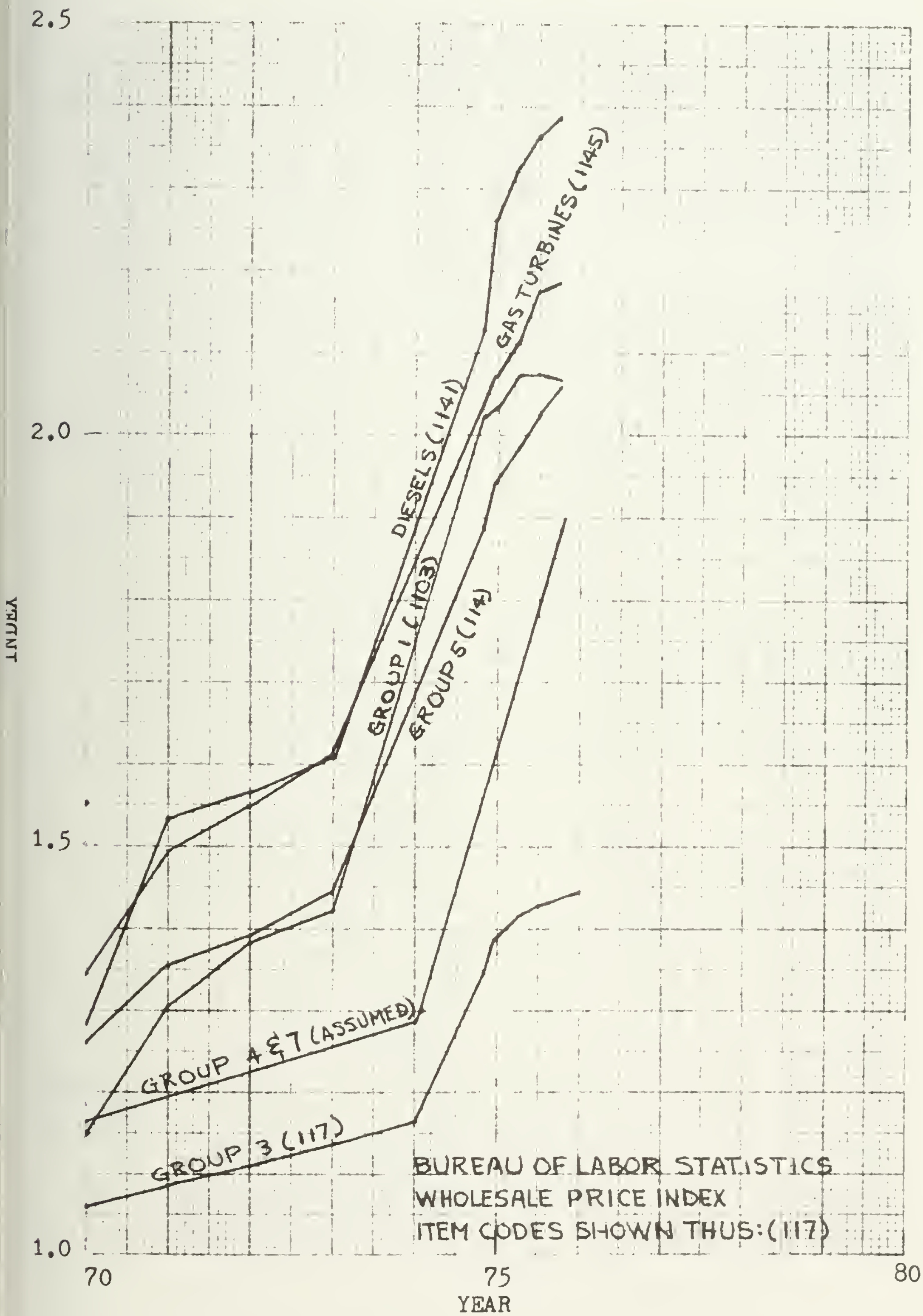
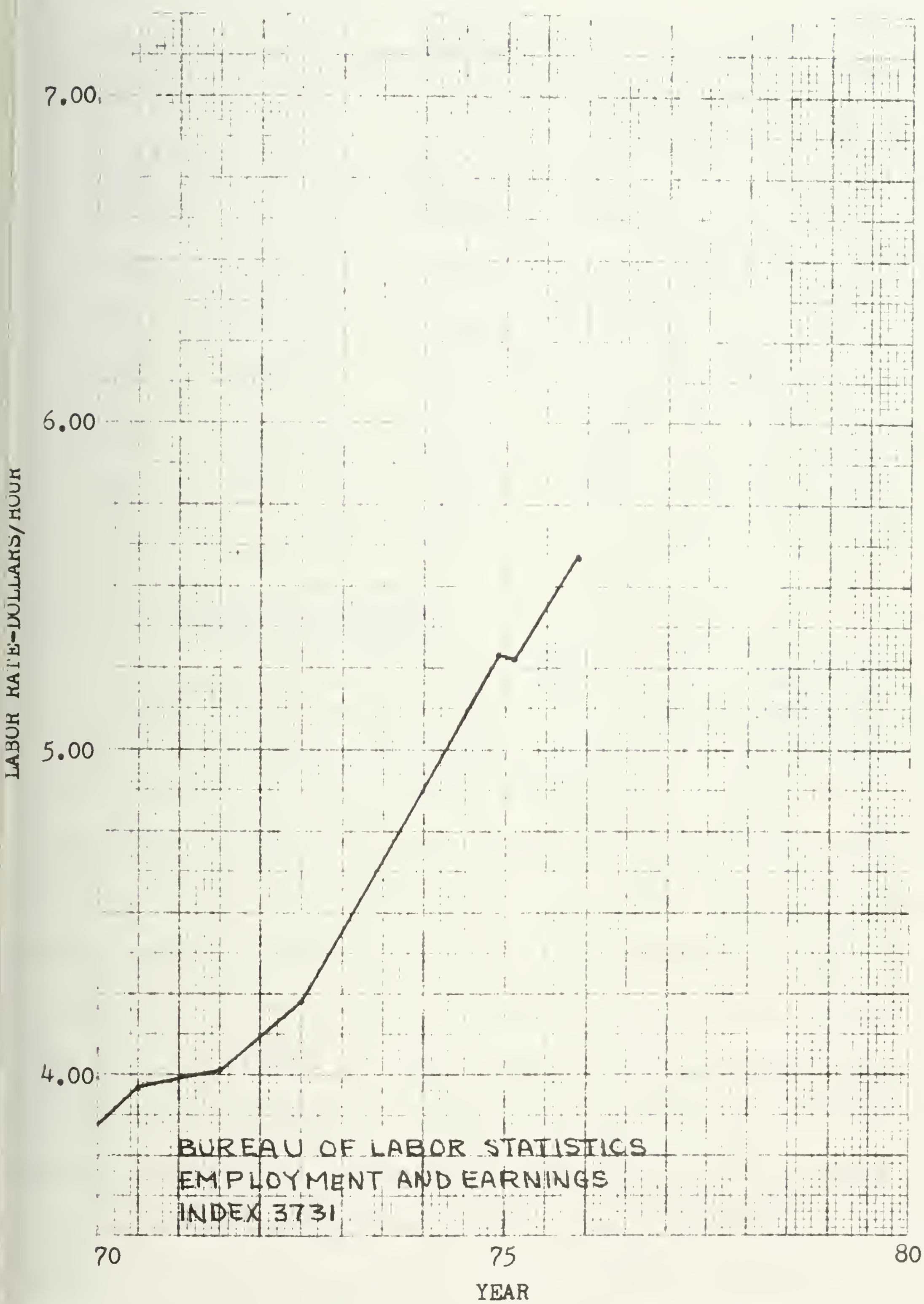


FIGURE 32: LABOR RATES VERSUS TIME



6.12.2 Input List for Subroutine COST

CSTG2 (JOPT=2 only)	LC(MM)	MOPT	LC(CC)
CSTG4	LC(MM)	MTYPE	LC(CC)
CSTG7	LC(MM)	WTG1	LC(WW)
DBMAR	LC(WW)	WTG2	LC(WW)
DOLHR	LC(NN)	G6IND	LC(NN)
G1IND	LC(NN)	WTG3	LC(WW)
G2IND	LC(NN)	WTG4	LC(WW)
G3IND	LC(NN)	WTG5	LC(WW)
G5IND	LC(NN)	WTG6	LC(WW)
JOPT	LC(CC)	WTG7	LC(WW)
LEN	SDCA		

6.12.3 Program Development

The assumptions made in this routine are many. Materials costs re based on representative items in the Wholesale Price Index. Group data are based on cold rolled steel plate, group 2 and 5 data are based n pumps and compressors, group 3 data are based on small electric nachinery, group 6 data are based on steel furniture and groups 4 and 7 nust be assumed at the prices in the construction year. Figure 31 shows n assumed curve for groups 4 and 7 which may be used to estimate rices if an old estimate is known. Eighty percent overhead and ten ercent profit are assumed. Miscellaneous cost items are assumed as ollows: initial output, 2 percent of total cost; spares, 9 percent of group materials cost plus 8 percent of group 3 materials cost plus 25 percent f group 4 materials cost plus 10 percent of group 5 materials cost; retrofit, 4 percent of total cost; and 3.5 percent for administrative costs.

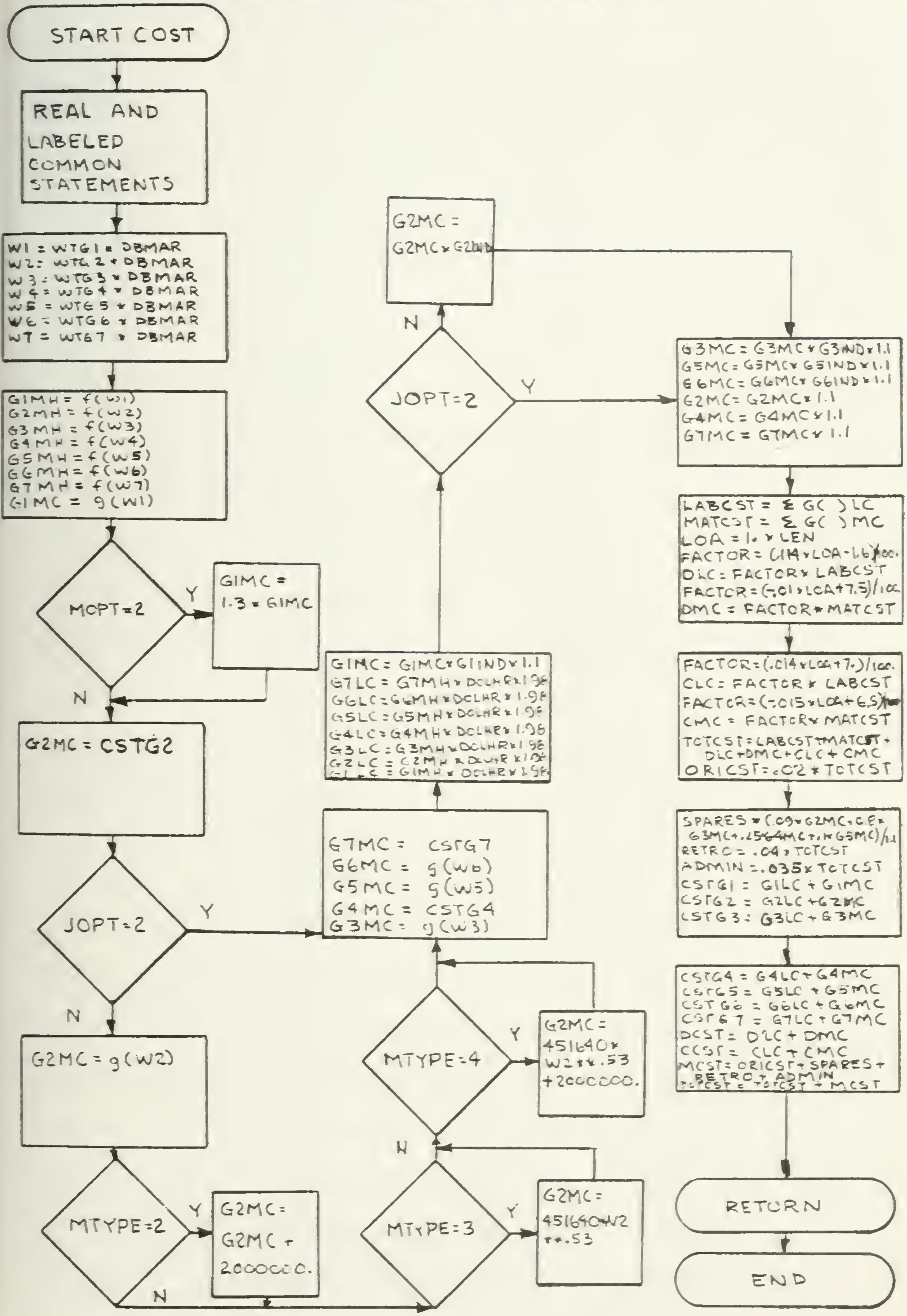
Several changes in the relationships presented previously are necessary to include four machinery options and two materials options and ccount for the difference in SWATH geometry. For Diesel propulsion he routine is unchanged; for Diesel-electric an additional $2,000,000 is dded. For gas turbine propulsion a new relationship was determined rom 1971 data. Thus any cost index applied should be related to the 971 value rather than that which is shown in Figure 31 directly. There s a good possibility of error in this calculation. For gas turbine-electric ropulsion, $2,000,000 is added to the value for gas turbine propulsion. f aluminum structure is specified, the materials cost for group one is ncreased 30 percent. For calculating the design and construction ervices costs, the Coast Guard procedure uses the length overall rather han the length between perpendiculars. For SWATHS it is assumed that he proper length for computing the FACTOR in making these calculations s the hull length.

A word of caution should be added here regarding the possibility of ost estimation errors. In this program group 2, 4 and 7 costs may be nputs into the calculation and may form a large part of the total ship ost. Input values are not corrected for inflation by the program. Any nput value must be corrected for inflation before input or the result may e unreasonable.

6.12.4 Flow Chart

A flow chart of this routine is shown in Figure 33.

FIGURE 33: COST SUBROUTINE FLOW CHART



6.12.5 Output List for Subroutine COST

CCST	LC(MM)
CSTG1	LC(MM)
CSTG2 (JOPT=1 only)	LC(MM)
CSTG3	LC(MM)
CSTG4	LC(MM)
CSTG5	LC(MM)
CSTG6	LC(MM)
CSTG7	LC(MM)
DCST	LC(MM)
MCST	LC(MM)
TOTCST	LC(NN)

6.12.6 Nomenclature List

The definition of all variables is the same as that given in the MAIN rogram nomenclature except for the following:

ADMIN	administrative costs, dollars
CLC	construction services labor cost, dollars
CMC	construction services material cost, dollars
DLC	design labor cost, dollars
DMC	design materials cost, dollars
FACTOR	multiplier for design and construction services costs
G1LC	weight group 1 labor cost, dollars
G2LC	weight group 2 labor cost, dollars
G3LC	weight group 3 labor cost, dollars
G4LC	weight group 4 labor cost, dollars
G5LC	weight group 5 labor cost, dollars
G6LC	weight group 6 labor cost, dollars
G7LC	weight group 7 labor cost, dollars
G1MC	weight group 1 material cost, dollars
G2MC	weight group 2 material cost, dollars

G3MC	weight group 3 material cost, dollars
G4MC	weight group 4 material cost, dollars
G5MC	weight group 5 material cost, dollars
G6MC	weight group 6 material cost, collars
G7MC	weight group 7 material cost, dollars
G1MH	weight group 1 man-hours
G2MH	weight group 2 man-hours
G3MH	weight group 3 man-hours
G4MH	weight group 4 man-hours
G5MH	weight group 5 man-hours
G6MH	weight group 6 man-hours
G7MH	weight group 7 man-hours
LABCST	total construction labor cost, dollars
LOA	length overall, feet
MATCST	total construction material cost, dollars
ORICST	initial output cost, dollars
RE	endurance nautical miles - RGEND in MAIN
RETRO	retrofit cost, dollars
SFCH	specific fuel consumption at half power - SFCHHP in MAIN
SFCM	specific fuel consumption at full power - SFCMHP in MAIN
SPARES	spare parts cost, dollars
VE	endurance speed, knots - VEND in MAIN
W1	weight group 1 with margin, tons
W2	weight group 2 with margin, tons
W3	weight group 3 with margin, tons
W4	weight group 4 with margin, tons
W5	weight group 5 with margin, tons

W6	weight group 6 with margin, tons
W7	weight group 7 with margin, tons

6.13 Subroutine OUTPUT

6.13.1 Purpose and Approach

This subroutine prints all the program output except the error messages printed in the XECUTE subroutine. The subroutine is divided into two major sections, the input data printing section and an output data printing section. The input data section lists all the input data supplied to the program including the payload listings, manning, cost indices, mission and performance inputs, options and the input length. If an error message is generated no further printing will occur for the given input case. If there is more data, the program will cycle and operate on the new data set.

If the program completes the calculation successfully, the output data will also be printed. The output data consists of dimensional data, weight, center of gravity and cost data, area data and a series of ratios and coefficients which may be useful for comparison of design alternatives.

6.13.2 Inputs Required

All of the inputs required for printing the outputs to the program have previously been stored in Labeled Common Blocks as a result of inputing a value or calculating the value in another subroutine. The data stored in these common storage areas are all required inputs to this subroutine. No additional listing of the common storage will be made here.

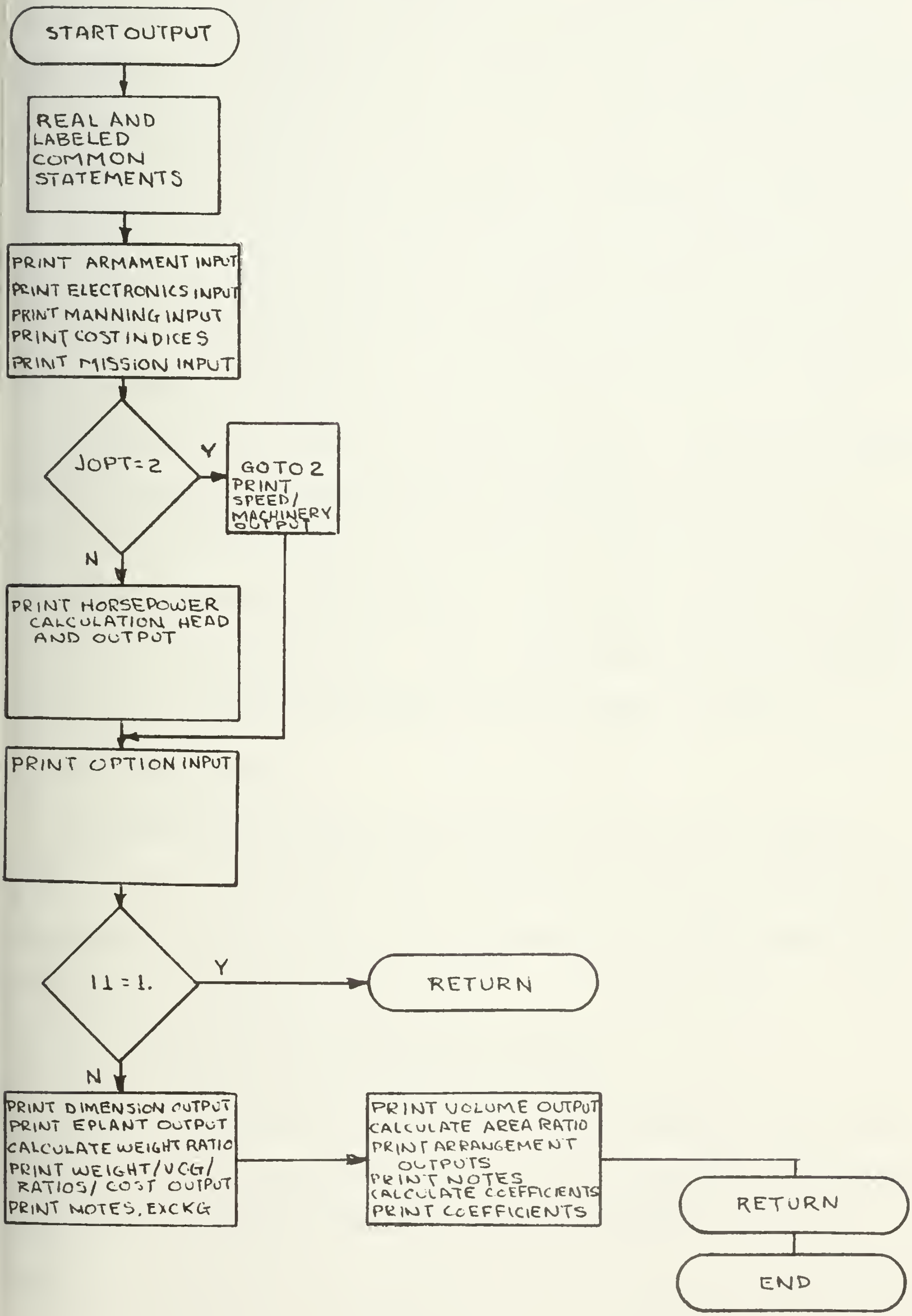
6.13.3 Program Development

The format of the output documents of this program has been modeled fter that of Goodwin to provide for easy comparison of SWATH and conentional displacement ships. Certain modifications are made to accept ıe geometry of the SWATH.

The subroutine consists primarily of FORMAT and WRITE stateıents. These statements will not be described in detail, but the order nd purpose of each will be noted. First the heading statement is printed; ıis provides the basic identification of the run. The input payload data s then printed. Armament, aircraft, cargo and electronics input data ill appear in the same form as the input data cards. Next the manning nputs are listed. Manning inputs are followed by cost indices, military ıission input parameters and the vehicle performance inputs. If the ıachinery plant is specified, the specifications of the machinery plant hich were input will be listed as output. If the machinery is not specified nd the maximum speed, endurance speed, endurance range and propulsive oefficient are input, these values are listed as output. Next the options nputs--machinery type, material type, free surface correction, margins nd length are listed. This completes the listing of input data. The rogram then tests for the existence of any error messages. If there are rrors in the program execution, the print stops and control is returned o XECUTE.

The output data fields begin with a summary of the ship dimensions s calculated. The hull volume and generator size are then output. Veight fractions of full load and light ship displacements with margins

FIGURE 34: OUTPUT SUBROUTINE FLOW CHART



re computed for each of the weight groups. The weight, center of ravity, weight fractions and cost data are then printed out for each eight group and for the light ship. Payload fractions are then computed nd a listing of the payload weights, centers of gravity and weight fractions re printed out for the full load ship. After printing some explanatory otes and miscellaneous cost figures the program computes volume per- entages for machinery, tankage and arrangements area; these data are lso printed. The next section of the program computes area ratios for ach type of space in the design model and prints out the area value omputed and the area ratio for each type of space. Finally the program omputes a number of coefficients-the habitability volume per man, veight of machinery per shaft, horsepower, volume of machinery spaces er shaft horsepower, vehicle density, weight group one density, payload ost fractions and VCG/D value. After completing printing, control is returned to the XECUTE subroutine and more input is sought.

6.13.4 Flow Chart

A simplified flow chart of the OUTPUT subroutine is shown in Figure 34. Note that this flow chart shows the two decision nodes in the subroutine and indicates what type of operations are being performed without listing all the statements.

6.13.5 Output List for Subroutine OUTPUT

No values are generated in this subroutine which are to be used elsewhere. All the values generated and stored in previous subroutines and the values calculated in this subroutine are output in the output listing.

6.13.6 Nomenclature List

All the variables used in this subroutine with the exception of several dummy variables used to make calculations within the routine have been defined previously.

AAVOM	available arrangements volume, cubic feet
AR	total arrangements area, sq ft
ARE	sum of the input required areas, sq ft
COEFm	dummy variable used for comparison coefficients
EXAR	excess area, sq ft
HABSPC	habitability space, sq ft
Rn	dummy variable used for volume and area ratios

CHAPTER VII
EVALUATION

The SWATH synthesis model developed in this thesis may be used to test the feasibility of a set of input design parameters for a SWATH ship. The parameters of the feasible design which are produced as outputs may be used as inputs for the preliminary design validation phase. These output parameters compare favorably with these generated by the Navy for a Coast Guard-operated SWATH and fall within the limits of the existing data base. The program has shortcomings and is expensive to run. This chapter reviews the problem areas in the program and examines the reliability of outputs by comparing the outputs of this program with Navy-generated designs.

Four areas of difficulty can be identified in the program; the arbitrariness of several of the estimating relationships, the oversizing of the electrical plant, the overestimation of structural weight and the determination of shaft horsepower. To improve on the estimating relations, there is no alternative to generating a larger data base. As there is but one operating SWATH in existance and only on the order of hundreds of design studies, the best way to validate estimating relations appears to be construction of a prototype or series of prototype ships of this design type. An effort has been made to incorporate data into the data base for estimates as it became available, but this effort must continue to insure the best design data.

Goodwin noted in evaluating his program that the electric generator capacity calculated reflected the policy of the Coast Guard for new designs

and is not an error in the program even though it tends to overestimate the required capacity considerably. Since this program uses the same method as Goodwin to estimate generator requirements, the results appear to be high. For instance, for a 240 foot SWATH design, this model indicates that either three 750 KW generators, three 1000 KW generators or three 1500 KW generators will be required. The total ship's load ranges from 650 to 1030 KW. With a load including growth, deterioration and starting loads of 1030 KW, a set of 1000 KW generators probably are sufficient, not the 1500 KW generators calculated. This type of trade-off is required at a later stage of the design than is considered in this model, however.

A third area of difficulty in the program output is in the estimation of a group 1 weight. In this program no structural analysis is attempted; data from previous designs has merely been used as a starting point. The program also assumes that the box is longer than the struts. This may appear to be a logical and reasonable assumption but its consequences may not be clear. The box length has an impact on the number of decks in the box and the structural weights. The extra box length requires cantilever structures forward and aft. If the box length is reduced, the enclosed volume may not be sufficient for arrangements on one level and another deck will be added to the box. This leads to an improvement in the use of structural material due to the deeper, more rigid box structure, but it leads to excess volume. The vehicle density of the two deck ship can be reduced and still meet the structural criteria. This can be seen by referring to Figure 24. The relationships tend to estimate from three percent low to ten percent high when compared to Navy design

studies of similar sized SWATHs. On the Navy AGOR SWATH design a detailed structural weight estimate agreed better with the design model output value with <u>all</u> the margin than without margin. This indicates that the structural design problem for SWATHs is far from solved and that some conservation is desirable. This model provides for this conservatism in group 1 weight estimation, but this tends to make the ship larger and of deeper draft.

The last problem area in the program is horsepower calculation. This program uses a considerable simplification of the DRAG problem of Chapman[22]. This simplification requires that the geometric relationships be fixed in the DIM subroutine and transferred into the horsepower routine. No resistance optimizing procedure is used; DIM merely generates a "good" form for a SWATH. Since the hull form is not optimized from a resistance point of view and since the speed-power curve has some rather pronounced humps and hollows for SWATH forms, the horsepower required at endurance speed may be higher than that of an optimized SWATH form. The resistance of a SWATH form generated by this model 3335 tons displacement is approximately 30 percent higher than that of a conventional destroyer form at maximum speed and at the endurance speed of a destroyer, around 18 knots, the SWATH is starting up a pronounced hump in the speed-power curve.

Not only is the method used for calculating the horsepower requirements in this program an unoptimized solution, but it is an expensive way to find the required powering. In each iteration through the program, the horsepower calculation is made. This requires approximately 5 seconds on the IBM 370 computer; five iterations cost about $8.00. To limit

the time and money used in determining the horsepower, the program was monitored as it executed the dimension changes and horesepower calculations. It was found that after approximately five iterations the dimensions had stabilized such that further horsepower calculations do not result in significant changes. Table VIII gives an indication of this stabilization of dimensions. A control has been placed in the XECUTE routine which allows only five iterations before the HPCALC routine is bypassed. If an unrestricted run is desired this control loop may be removed. However, unrestricted running of the program may result in up to 40 iteration loops and a cost exceeding $40 for one ship run. The use of this horsepower calculation may not be economically feasible. It is also possible to remove the horsepower calculation from the program and substitute dummy values of the horsepower returned. This approach is reasonable if the user has a good estimate of the horsepower from another source.

The final section of this chapter compares the results of this model with previous studies conducted by the Navy. Several design outputs from the model are included in Appendix C. Table IXa shows a comparison of the 240 foot Navy SWATH AGOR, Ship 24, and the 240 foot Navy-designed SWATH CUTTER, Ship 25 in the data base, with the model output for a series of 240 foot ships with diesel-electric propulsion, gas turbine propulsion and with the machinery parameters specified and the speed of the ship calculated, the JOPT=2 option. Table IXb shows a comparison of the 155 foot Navy PMR patrol vessel, Ship 21, with the model outputs for the gas turbine propulsion/aluminum construction option and the diesel-electric/steel option. For further comparison the results of the Goodwin Cutter model synthesis of the 210 foot WMEC, 270 foot WMEC and 378 foot WHEC are also shown in this table. The notation "DUMMY" describing a ship indicates that the program has

TABLE VIII

STABILIZATION OF VARIABLES

Variable	Run	SHIP 1 DUMMY			SHIP 2			SHIP 3 DUMMY		
	Loop	4	5	29	1	4	5	1	5	13
Length		240	240	240	240	240	240	155	155	155
Diameter		17.93	17.93	17.53	15.53	16.93	16.93	11.55	13.56	13.56
Draft		31.38	31.38	30.68	27.18	29.63	29.63	20.22	23.72	23.72
Strut Length		193	193	193	193	193	193	125	122	125
Strut Beam		7.58	7.58	7.41	6.52	7.26	7.36	4.85	5.60	5.60
CWP		.942	.942	.942	.84	.941	.941	.858	.84	.856
Box Beam		89.73	86.73	83.33	89.33	87.73	86.73	61.66	67.65	67.66
Trail Displ.		3641	3641	3504	2755	3324	3336	95342	1214.77	1233.66
Molded Displ.		3590	3590	3456	2717	3279	3289	940.26	1198.00	1216.63
GMT		4.1	4.21	4.07	3.79	3.89	3.38	2.69	3.12	3.00
GML		551.32	553.75	564.38	103.08	579.30	584.94	113.28	47.81	94.79
Tons					2831	3319	3331			
SHP Max.		32000	32000	32000	14835	17374	17462	2800	2800	2800
Sust. Speed		24.250	24.250	24.250	20.00	20.00	20.00	15	15	15
SHP End.		3025	3025	3025	4691.8	5380	5430	1200	1200	1200
End. Speed		12.000	12.00	12.000	13.00	13.00	13.00	10	10	10
Job Option		2	2	2	1	1	1	1	1	1
Average KW		485	487	470	645	602	600	156	150	152
KW1		668	671	649	1086	1032	1028	224	217	219
Propulsion KW		70	70	70	71	71	771	15	15	15
Lub Oil		5.25	5.25	5.25	4.98	5.23	5.24	7.80	7.80	7.80
SFC		.705	.705	.705	.589	.590	.590	.506	.506	.506
WT Fuel		346.8	346.9	345.4	830.57	930	936	80.16	80.16	80.31
Enc. Vol.		460687	452380	436525	430472	462320	462178	175678	197515	201477
Mach'y Vol.		31323	31323	29941	19755	24026	24045	17861	22018	22018
WTG1		1756	1730	1665	984	1076	1074	483	583	504
WTG2		283	283	283	150	165	166	102	102	102
WTG3		130	129	127	193	198	198	44	47	47
WTG4		90	90	90	90	90	90	4	4	4

TABLE VIII (Continued

Variable	Run	SHIP 1 DUMMY			SHIP 2			SHIP 3 DUMMY		
	Loop	4	5	29	1	4	5	1	5	13
WTG5		253	249	242	239	253	253	108	120	123
WTG6		188	186	182	180	189	189	102	111	112
WTG7		17	17	17	17	17	17	6	6	6
WFULLD		3637	3599	3508	3076	3331	3336	1083	1221	1237
Total Depth		59.38		58.68			57.63			28.69
VCG		32.52		31.99			28.19			19.40
Cost $M				40.127						

TABLE IX a

COMPARISON OF DESIGN OUTPUTS

SHIP	AGOR 24	CUTTER 25	CUTTER 25	CUTTER MODEL	CUTTER MODEL	CUTTER MODEL
Material	Steel	Steel	Steel	Steel	Steel	Steel
Machinery	Diesel	D-E	G-T	D-E	G-T	G-T
Job Option	-	-	-	1	1	2
Length	240.	240.	240.	240.	240.	240.
Diameter	15.	15.72	15.43	16.78	15.53	16.03
Draft	16.25	27.51	27.00	29.37	27.18	28.06
Strut Length	200.	184.02	180.09	193.	193.	193.
Strut Beam	7.5	7.5	7.5	7.2	6.72	6.88
CWP	.89	.845	.842	.942	.942	.942
Box Beam	82.	85.02	82.82	81.58	77.33	77.83
Box Depth	13.	22.	22.	13.	13	13.
Box Length	171.	184.02	180.09	213.	213.	213.
Total Depth	59.25	64.51	64.00	57.42	55.16	56.09
Displacement	3019.12	3058.08	2947.63	3267.55	2853.38	3013.13
SHP MAX.	4842.	12880.	40000	15278	38611	32000
Sust. Speed	13.17	19.36	24.26	19.7	24.	22.67
SHP END.	3834.7	2609	2537	2974	2848	2305
END. Speed	13.	12.	12.	12.	12.	12.
Endurance	6000.	3000.	3000.	3000	3000	3000
Generators	4 x 350	4 x 500	4 x 500	3 x 750	3 x 750	3 x 750
WTG1	1130	1315	1267	1361	1232	1273
WTG2	213	380	283	440	274	283
WTG3	74	105	105	128	121	123
WTG4	19	90	90	90	90	90
WTG5	417	283	273	245	226	230
WTG6	235	201	198	184	173	175
WTG7	1	17	17	17	17	17
WLSHIP	2401	2749	2569	2834	2454	2519
WLSHIP/ WFULLD	.795	.899	.871	.867	.859	.835
WTFUEL	472	155	224	253	235	332
WFULLD	3032	3059	2948	3269	2857	3018
KG	34.84	40.23	38.40	32.44	30.67	30.40
VCG/DT	.588	.624	.602	.565	.556	.542
ENCVOL	341352	486256	465398	443809	402486	410984
MACH'Y VOL	-	-	-	40453	24082	25038
TANK VOL	-	-	-	19660	18109	23011

TABLE IXa (Continued)

SHIP	AGOR 24	CUTTER 25	CUTTER 25	CUTTER MODEL	CUTTER MODEL	CUTTER MODEL
Total Arrgt.	20733	33533	32069	25286	23025	23195
Hull Arrgt.	14022	31293	29829	19341	18306	18456
DKHSE. Arrgt.	6711	2240	2240	5945	4719	4739
HAB VOL/ MAN	-	-	-	559.2	559.2	559.2
WTG1/ ENCVOL	.0038	.00270	.00272	.00307	.00306	.00310
WTG2/ HP	.0505	.0424	.00708	.0288	.0071	.0088
MACH VOL/ HP	-	-	-	2.6477	.6237	.7824
WFULLD/ ENCVOL	.00899	.00629	.00633	.00737	.00710	.00734
WLSHIP/ ENCVOL	.00703	.00565	.00552	.00639	.00610	.00613
COST $M	-	26.36	29.96	40.99	54.19	38.18

Notes for Table IXa, b:

1) Dimensions in feet. Weights in tons. Speed in knots. Endurance in nautical miles.
2) Nomenclature

WTG	=	weight group
WLSHIP	=	light ship weight
WFULLD	=	full load weight
WTFUEL	=	weight of fuel
KG	=	vertical center of gravity location
VCG/DT	=	vertical center of gravity/total depth ratio
ENCVOL	=	total enclosed volume
HABVOL	=	habitability volume

TABLE IXb

COMPARISON OF DESIGN OUTPUTS

SHIP	PMR 21	PATROL MODEL	PATROL DUMMY	CUTTER MODEL 378 WHEC	270 WMEC	210 WMEC
aterial	Steel	Alum.	Steel	Steel	Steel	Steel
achinery	D-E	G-T	D-E	CODOG	Diesel	Diesel
ob Option	-	1	1	2	1	1
ength	155.	155.	155.	350	270[1]	210
iameter	9.5	10.81	13.56			
raft	16.70	18.91	23.72	14.60	13.42	9.12
rut Length	112.	125.	125.			
rut Beam	5.5	4.54	5.89			
WP		.928	.856			
ox Beam	54.	58.91	67.66	43.32	40.92	33.96
ox Depth		13	13			
ox Length		145	145			
otal Depth	39.70	43.78	48.55			
isplacement	786	871.33	1233.66	3062	1984	944
HP MAX	2800.	2605	2800D	36000	9139	4412
ust. Speed	15.	15	15	2644	19.7	17.29
HP END.		1124	1200D	2647	2838	1554
ND. Speed	5	10	10	14.	15	14
ndurance	2000	2000	2000	10500	6500	4000
enerators		3 x 500	3 x 250	3 x 1500	3 x 750	3 x 500
TG1	354	300	594	963	661	335
TG2	100	50	102	384	203	99
TG3	11	79	48	165	89	75
TG4	3	4	4	80	50	26
TG5	80	103	123	262	190	104
TG6	27	100	112	322	200	106
TG7	0	6	6	39	30	9
LSHIP	661	718	1107	2215	1465	753
LSHIP/ WFULLD	.841	.824	.895	.723	.738	.796
TFUEL	47	107	80	653	386	141
FULLD	786	872	1237	3061	1986	946
G		25.92	28.69	17.20	16.47	15.12
CG/DT		.592	.591	.58	.559	.621
NCVOL		166958	201479	368439	254816	133709
ACH'Y VOL		10602	22018	57390	44238	18178
ANK VOL.		6815	5608	36987	24526	16651

Shortest ship feasible in Goodwin Model.

TABLE IXb (Continued)

SHIP	PMR 21	PATROL MODEL	PATROL DUMMY	← CUTTER MODEL →		
				378 WHEC	270 WMEC	210 WMEC
Total Arrgt.		10479	11955	29664	20344	10661
Hull Arrgt.		9331	10724	18522	15180	8562
DKHSE Arrgt.		1148	1232	11142	5164	2099
HAB VOL/ MAN		650.4	650.4	491.2	512.9	549
WTG1/ ENCVOL		.00180	.00295	.00261	.00259	.0025
WTG2/HP		.0193	.0365	.0107	.0222	.0224
MACHY VOL/ HP		4.0701	7.8635	1.5942	4.8408	4.1175
WFULLD/ ENCVOL		.00522	.00614	.00831	.00779	.00707
WLSHIP/ ENCVOL		.00430	.00549	.00601	.00575	.00563
COST $M		22.23	19.40	29.37	30.136	8.521

uncated the horsepower calculation or dummy inputs have been made to ause the computer to loop across the HPCALC subroutine section.

The tables show that the values of the various parameters returned by e model are in the range of values given by the Navy studies. This odel produces ships which tend to be somewhat larger, have more dis- lacement and have larger draft. The displacements returned by the odel for the 240 foot ship range from two percent more to three percent ess than the Navy results. It is more difficult to compare the 155 foot hip because the input payloads are different, but the best agreement of isplacement at this size is 11 percent. Conservative estimates of tructural weights, an apparent overestimate of the generator size and onservative fuel rate estimates combine to increase displacement. hese effects are more severe for the smaller ship. In general the odel calculates a vertical center of gravity location somewhat lower an the Navy studies. This may be due to the larger fuel weight located the hulls. The cost estimates show that the SWATH ship is likely to be ore expensive to acquire than the conventional ship. In conclusion, e outputs of the model for the various options specified show consider- ble bracketing of the outputs of Navy design studies.

CHAPTER VIII
CONCLUSIONS AND RECOMMENDATIONS

This thesis has investigated the use of the SWATH ship for Coast Guard pplications and developed a set of estimating relationships in a computer hip synthesis model which can be used as a design tool for feasibility and reliminary design studies.

The SWATH Model is a reasonable basis for design studies for this articular type of hull form. The model is not applicable to any other eometry, but can be used in conjunction with the Cutter Model to generate nformation from which decisions may be made on design approaches.

The SWATH Model is limited by a small data base and must be used ith caution until additional checking of the results has verified the method. dditions to the data base may help to confirm or invalidate certain estiating relationships. Although the outputs are reasonably close to the ata base, the large number of variables and assumptions required in the nodel make correspondence of output unlikely.

Two estimating relationships used in the model noticeably overestimate. he structural weight and the electrical plant size both are estimated using he best information available or the present design policy, yet both lead o excessive values. The conservatism in the structural weight deterination can probably be investigated by a manual study following applicaion of the model. The generator oversizing must also be evaluated on a hip-by-ship basis. Applying a service factor to the requirements and thus educing the required generator size is one approach which has been considered but not used because load analyses to determine the value of the ervice factor have not been calculated.

The method of horsepower calculation used by the SWATH model is too umbersome and inefficient for use in a ship synthesis model which will e used often. Although the resistance prediction is a good routine, it s too expensive to run often and should be improved.

The results of the SWATH Model show general agreement in principal haracteristics with ships in the data base for which comparisons have een made. Thus the model can be used for SWATH design studies and verage ships will result.

There are six areas of study where improvements can be made to the nodel: (a) a seakeeping and ship motion extension, (b) a sensitivity nalysis, (c) more detailed weight and center of gravity data, (d) better stimating relationships for arrangement area, (e) a reanalysis of lectric generation requirements and (f) a powering study and a new nethod for determining horsepower.

The advantages of the SWATH configuration include limited motions and oss of speed in a seaway. Although the program now calculates a set of easonable dimensions for the ship, it does not calculate any ship motion r speed reduction in a seaway data. This information would be very seful in determining the in-service performance of the ship. Preliminary nalyses of motions data for SWATHs have been made (7, 25, 26, 27) and stimation methods can be derived. Many variables are involved, however, nd the calculation may be complex. A motions routine could be added o the program after the VCG routine.

The effects on the outputs of variations in certain parameters and ssumptions is another area for study. One assumption which would be

easy to vary and which should produce major variations is the assumed box length. Variations of strut length plus or minus 20 feet would provide a range of values within the data base. Altering one card in the DIM routine could affect this change. Although somewhat more difficult to vary, some of the assumed geometry could be varied. For instance, the strut could be turned around on the hull to investigate the change in resistance.

Certainly better and more detailed data for weights, vertical center of gravity location and required arrangement areas would be useful in insuring that the best possible data is input to the program. Unfortunately, new data becomes available slowly and it must be added to the data base and the relationships must be reevaluated. This is a time-consuming and dull task, but it must be done if the model is to stay current and be improved.

The need for reassessment of the electric power requirements and the possibility of applying a service factor to reduce the size of the installed generator is mentioned above. The approach which has been used in these models appears to be too simple. This simplistic approach is the reason for overestimation. A more detailed analysis of the real power requirements as a function of the operational condition, environment and time of day, for instance and a detailed load analysis is recommended to determine the actual requirements for electric power.

The most important area where improvement is required is in the horsepower prediction. The present HPCALC uses a 400 term expansion for wave drag which must be calculated for each speed. This routine is inefficient. The generation of an array of drag coefficient values as a

function of many geometric parameters and a speed seems a logical approach to solving this problem. Given the table of drag coefficients as functions of speed and geometry, a resistance estimate could be made in the same manner as that used in the DD07 and Destroyer and Cutter Models-interpolation of a coefficient value in a large array. This procedure is considerably more efficient than the iterative calculation used in this program. The difficulty will arise from the generation of the drag coefficient array. The most significant geometric parameters must be chosen as the dimensions of this array. This means that the significant variables must first be reduced to seven or fewer to make the problem tractable by computer. The evaluation of the array elements in a seven dimensional array also poses some complex programming problems. A series of drag coefficients for strut wave making and friction drag has been calculated for limited cases by Chapman(12) for a range of waterplane areas and speeds.

Finally it must be emphasized that the SWATH model is intended as a design tool. It must be validated by manual calculations and drawings. It must be updated as more data is available. It provides only feasible designs and may reject a set of input requirements which are nearly feasible solely on the basis that a program constraint is violated. It should not be used as a optimization routine or as part of an optimization program; it is intended for presenting consistent design parameters to the decision maker in a readily useable format. Optimization criteria and decisions are left to the decision maker.

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APPENDIX A
USER'S GUIDE

This appendix describes the input information required by the model in sufficient detail for the SWATH designer to prepare a set of input data cards for the computer. Guidelines for input values which may be varied to suit design requirements are noted and suggested values are given. A list of payload input data is provided as the beginning of a "shopping guide". Note that electrical requirement data is missing from this guide. These guidelines for input values and the "shopping guide" are only starting points for the design process. In order for the computer to produce reliable results the values of input values must be as realistic and accurate as possible. Previous designs may form a good starting point for such input data. A compilation of principal dimensions of previous SWATH designs is to be found in Section 6.1 of this thesis.

The input data deck for this program has been patterned after that of Goodwin to make use of the two programs by the same designer relatively easy. There are, of course, differences in the input data requirements due to the differences in the hull forms.

The minimum number of types of data cards in the input deck is 14. Several cards of one type may be required or desirable to describe the ship adequately. Where this is the case, a notation will be made in the description.

Card Type I: This card controls the reading of an input data deck.

The values which can be used are:

0--which will cause the program to stop, and

1--which will cause the program to read the following input data.

This control index must be entered in card column 1. (FORMAT I1)

Card Type II: This card provides a heading which will be printed out above the output. All 80 card columns may be used for any alphanumeric description desired. (FORMAT 20A4)

Card Type III: This card gives the total number of armament, aircraft and cargo payload data cards which follow in the data deck. The maximum number is 20. This number should be entered on the card in columns 1 and 2 right justified. (FORMAT I2)

Card Type IV: This is a set of cards containing the armament, aircraft and cargo payload data. The number of these cards is the number entered in card type III. Each of the values entered on this card must contain a decimal point; descriptive data entered on this card is in alphanumeric characters. (FORMAT 5A4, 12F5.0)

Each of this type of card must have the following format:

Columns 1-20: Any alphanumeric title describing the remainder of the data on the card.

Columns 21-25: Cargo weight in tons.

Columns 26-30: Cargo vertical center of gravity entered as the ratio of the expected cargo vertical center (VCG) divided by the depth of the ship to the main deck, D.

Columns 31-35: Group 7 weight in tons.

Columns 36-40: Group 7 vertical center of gravity location as the ratio of VCG/D.

Columns 41-45: Ammunition weight in tons.

Columns 46-50: Ammunition vertical center of gravity ration, VCG/D.

Columns 51-55: Aircraft weight in tons.

Columns 56-60: Aircraft vertical center of gravity ratio, VCG/D.

Columns 61-65: Electrical load in kilowatts.

Columns 66-70: Deckhouse area required for this payload item in square feet.

Columns 71-75: Hull area requirement in square feet. If this payload item has no specific requirement for area in the deckhouse, all the arrangement area required should be listed in the hull.

Columns 76-80: Group 7 acquisition cost in thousands of dollars corrected to the year in which the cost estimate is to be made.

Except for the moment arms, all the values input in these cards are summed by the MAIN program and only the sum is used in calculations. It makes no difference to the program whether these data are input on one or several cards. For each input card, however, the VCG/D value must apply to the weight which immediately precedes it. All values which are to be included in the total Group 7 light ship weight must be input on these cards. Any make up feed, hydraulic oil or similar special fluid must be included as a cargo item as the program does not account for them.

If there is no payload data, a 1 should be entered in column 2 of card ype III and a single blank "payload" card should be included for card ype IV.

Card Type V: This card gives the total number of electronics input data cards which follow in the data deck. The maximum number is 20. This number should be entered on the card right justified in columns 1 and 2. (FORMAT I2).

Card Type VI: This is a set of electronics input data cards. The number of these cards is the number entered in card type V. Each of these cards has the same format--a description of the input and a list of data for calculations. Each data entry must contain a decimal point. (FORMAT 5A4, 6F5. 0). Each card has the following format:

Columns 1-20: Any alphanumeric title describing the remainder of the data on the card.

Columns 21-25: Group 4 weight in tons.

Columns 26-30: Group 4 vertical center of gravity ratio, VCG/D.

Columns 31-35: Electrical load in kilowatts.

Columns 36-40: Deckhouse area required for this payload item in square feet.

Columns 41-45: Hull deck area required, that is, the remaining area required in square feet.

Columns 46-50: Group 4 acquisition cost in thousands of dollars corrected for the year in which the cost estimate is to be made.

These data may be arranged in any convenient way except that for each veight item there must be a VCG/D entry immediately following. It is particularly important to insure that only the required deck area is to be placed in the deckhouse; if an area may go either in the hull or deckhouse, it should be entered as a hull area.

This is the only way in which group 4 weights, vertical centers and costs are entered into the program. Therefore all group 4 weights to be entered into the light ship weight including navigation equipment must be entered on these cards.

If there is no electronics data, a 1 should be entered in column 2 of card type V and a single blank "electronics" card should be included for card type VI.

Card Type VII: This card is used to specify the number of officers, Chief Petty Officers and enlisted men comprising the crew. All numbers should be right-justified integers. (FORMAT 3I5).

Columns 1-5: Number of Officers.

Columns 6-10: Number of Chief Petty Officers.

Columns 11-15: Number of enlisted men.

Card Type VIII: This card is used to specify the cost indices and the labor rate to be used in computing the cost of the ship. Values for cost indices and labor rate are provided in Figures 31 and 32 in Section 6.12. Each of these values must contain a decimal point. (FORMAT 6F5.0) The values must be entered on the card as follows:

Columns 1-5: Labor rate in dollars per hour, for example, 5.85.

Columns 6-10: Group 1 cost index, for example, 1.65.

Columns 11-15: Group 2 cost index.

Columns 16-20: Group 3 cost index.

Columns 21-25: Group 5 cost index.

Columns 26-30: Group 6 cost index.

Card Type IX: This card contains the Military Mission Specifications. All values on this card must contain a decimal point. (FORMAT 3F5. 0).

Columns 1-5: Endurance days for dry provisions.

Columns 6-10: Weight of aircraft fuel in tons.

Columns 11-15: Vertical center of gravity ratio, VCG/D, for the aircraft fuel.

Card Type X: This card gies the job option input (JOPT). Two options are available:

1-- which allows the user to input the sustained speed desired and have the computer calculate the required horsepower, and which requires the use of input card type XI A, or

2--which allows the user to input the machinery plant particulars and have the computer calculate the speed, and requires input card type XI B.

This control index must be entered in card column 2. (FORMAT I2)

Card Type XI A: This card describes the vehicle performance specifications. It is used when a JOPT value of 1 is specified on card Type X. All values require a decimal point. (FORMAT aFb. 0) The inputs are as follows:

Columns 1-5: Sustained speed in knots.

Columns 6-10: Endurance speed in knots.

Columns 11-20: Endurance range in nautical miles.

Columns 21-25: Propulsive coefficient.

Only one value of propulsive coefficient is input in this model. SWATH model test data have shown little variation in values of propulsive coefficient from approximately 0.74 to 0.70. A value of 0.70 is suggested for use in the program.

Card Type XI B: This card describes the machinery specifications. It is used when a JOPT value of 2 is specified on card type X. Due to the several possible arrangements and types of machinery plants applicable to the SWATH, this is a complex entry. The inputs are as follows:

Columns 1-5: Maximum sustained horsepower/1000. Requires a decimal point. (FORMAT F5.0)

Columns 6-10: Total group 2 weight in tons. Requires decimal.

Columns 11-15: Specific fuel consumption at maximum horsepower, pounds per shaft horsepower-hour. Requires decimal.

Columns 16-20: Specific fuel consumption at half horsepower, pounds per shaft horsepower-hour. Requires decimal.

Columns 21-25: Endurance speed in knots. Requires decimal.

Columns 26-35: Endurance range in nautical miles. Requires decimal.

Columns 36-40: Propulsion auxiliaries electrical load in kilowatts Requires decimal point.

Columns 41-45: Propulsive coefficient. Requires decimal.

Columns 46-50: Group 2 acquisition cost in thousands of dollars, corrected for inflation for the year in which the cost estimate is to be made. Requires decimal.

Columns 51-55: Weight of lubricating oil, in tons. Requires decimal.

Column 56: Location of propulsor. The program accepts only the value 1 for propulsor located in the hulls. Integer.

Columns 57-61: Length of propulsor space in feet. Requires decimal point.

Column 62: Location of prime mover. If the prime mover is to be installed in the hulls the value of 1 should be input; if the prime mover is to be located in the box structure the value 2 should be used. Integer.

Columns 63-67: Length of the prime mover space in feet. Decimal.

Columns 68-72: Width of the prime mover space in feet. Decimal.

Columns 73-77: Height of the prime mover space in feet. Decimal.

Card Type XII: This card contains information about the options to be used in the calculation and the basic input parameter for the program, the ship size, expressed as length. The card must be of the following format:

Columns 1-2: Machinery type option input. A right-justified integer is entered in column 2. The various options are:

MTYPE=0 - This causes the program to return to card type I to read in new input data.

MTYPE=1 - A Diesel plant will be installed

MTYPE=2 - A Diesel-electric plant is specified.

MTYPE=3 - A gas turbine plant is specified.

MTYPE=4 - Specifies a gas turbine-electric plant.

If JOPT is 2 on card X, any value of MTYPE except 0 may be specified. f an MTYPE value other than 0-4 is specified and horsepower required s less than 30000 and the hull diameter is more than 18 feet, the program lefaults to Diesel propulsion located in the hulls. Allowing this default ption to occur is NOT recommended.

Columns 3-4: Materials Option. A right-justified integer is entered in Column 4. The options are:

MOPT=1 - A steel hull and box with aluminum superstructure is specified.

MOPT=2 - An all aluminum structure is specified.

Columns 5-9: Free Surface Correction in feet. Requires a decimal point. The free surface correction need not be a positive number; a negative free surface correction is interpreted as a reduced value of KG.

Columns 10-14: Length of the ship's hull in feet. This entry requires a decimal point.

Columns 15-19: Design and builders margin entered as a decimal fraction such as 0.15. A margin of 15% is commonly used for preliminary design studies on SWATHS.

Card Type XII may be repeated many times using variations of length or options and the same payload description. Each card XII is interpreted as another design case. It is often advantageous to generate a range of ship sizes and types to assist in determining an optimum. It is suggested that due to the iteration required in the ship dimension routine length variations be started from shorter ships and continue to longer ships, however this is not required.

Card Type XIII: This card is an indicator which directs the computer to read a completely new input case with a new payload and performance description. A value of 0 in column 2 of this card will cause a new card type I to be read.

Card Type XIV: This card is a card type I. If more data is to follow, a value of 1 must be entered in column 1; if a value of 0 is entered in column 1, the computer will stop.

A sample listing of the required input data cards is given below. The data shown refers to a 240 foot Medium Endurance Cutter for Fisheries Law Enforcement.

```
 1
GROUP 7                 0.    0.  16.7  1.06 4.9   .8925.   1.1 15.  2000. 200.301.2
 1
GROUP 4                90.    1.0 25.  887. 1239.2157.
   13   10   80
 5.80 2.25 2.18 1.63 1.84 1.98
 20. 91.     .11
 1
 19.7 12.       3000.   .70
 2 1 .5   240.   .15
 0
1
***COAST GUARD SWATH SYNTHESIS MODEL*** 240 FT MEC FOR FLT  MAY 76 GT $ FY 76***
 1
GROUP 7                 0.    0.  16.7  1.06 4.9   .8925.   1.1 15.  2000. 200.301.2
 1
GROUP 4                90.    1.0 25.  887. 1239.2157.
   13   10   80
 5.80 2.25 2.18 1.63 1.84 1.98
 20. 91.     .11
 1
 24.  12.       3000.   .70
 3 1 .5   240.   .15
 0
1
***COAST GUARD SWATH SYNTHESIS MODEL*** 240 FT MEC FOR FLT  MAY 76 G2 $ FY 76***
 1
GROUP 7                 0.    0.  16.7  1.06 4.9   .8925.   1.1 15.  2000. 200.301.2
 1
GROUP 4                90.    1.0 25.  887. 1239.2157.
   13   10   80
 5.80 2.25 2.18 1.63 1.84 1.98
 20. 91.     .11
 2
  32. 283.  .56  .64  12.      3000.  70.  .708999. 5.251  35.1  27.  14.  14.
 3 1 .5   240.   .15
 0
0
```

TABLE A-I

PAYLOAD DESCRIPTION DATA

A. SHIP SYSTEM LEVEL

Ship	Group	Weight	KG	KG/D	KW	DHAR	HLAR	Cost x 10^{-3}
378' WHEC	400	11.30	22.99	.826				
	401	19.15	28.82	1.035				
	402	10.35	37.90	1.362				
	403	9.20	25.98	.934				
	404	29.03	34.58	1.043				
	450	5.44	29.65	1.065				
	4 Total	84.47	30.88	1.109	117.8	1307	468	2280
	700	25.66	38.87	1.397				
	701	2.23	20.02	.719				
	702	3.55	25.08	.901				
	750	2.08	24.97	.897				
	751	0.42	34.00	1.222				
	7 Total	33.95	35.27	1.267	46.46	1409	2256	196
210' WMEC	400	2.63	28.19	1.529				
	401	2.91	24.58	1.334				
	402	1.11	14.18	.769				
	403	5.45	19.26	1.045				
	404	3.42	43.93	2.384				
	450	3.15	38.97	2.114				
	4 Total	18.67	28.88	1.568	21.99	319		190
	700	3.40	32.46	1.761				
	701	2.00	21.00	1.139				
	702	1.60	16.50	.895				
	750	0.40	8.00	.434				
	751	0.						
	7 Total	7.40	24.59	1.334	0.0		385	76
SWATH CUTTER	4 Total	90.00	64.00	1.00				
	7 Total	16.70	67.50	1.055				
SWATH AGOR	4 Total	1.92			5.20			

TABLE A-I (Cont.)

B. PAYLOAD ITEM DESCRIPTIONS:

Item	Group	Weight Tons	KG reference Main Dk	DHAR sq ft	HLAR sq ft	Cost x 10^{-3} 1968 dollars
ECM DE Basic	404	4.5	+15.5	270		260
ECM WLR-8	404	1.7	+12.	20	100	345
RADAR SPS 10 IFF	408	.9	+19.5	70		50
RADAR SPS 29	408	7.5	+	180		150
RADAR SPS 53	408	.14	+20.	15		14
RADIO DE non ASW	409	9.7	-5.5		800	270
RADIO small ship	409	4.0	+5.	200	100	60
SONAR UQN-4	412	.5	+10.	10		23
SONAR ETAS	412	22.8	+4.		210	1670
SONAR 505	412	8.5	9.0		440	530
NTDS DDG	413	40.0	+15.5	1350		3800
GFCS MK 86	402	7.93	+20.	350		2640
GFCS MK 56	402	10.6			160	110
GFCS MK 92	402	10.0	+15	180		3120
NIXIE	403	10.0				59
FCS CHAFFROC	405	.5	+25.	50		64
FCS HARPOON	405	.4	+30.	20		347
UBFCS MK 116	406	6.	+13.	90		833
LAMPS CONTROL	406	9.4	+20.	300		2300
LAMPS PACKAGE	406	.4	+13.	25		587
5"/38 SM	700	29.7	+8.	180	70	55
50 cal. MG	700	.15	+15.			2
76mm OTO MELARA	700	6.0	+10.		100	430
CHAFFROC	704	1.3	+36.	100		100
HARPOON LAUNCHER	704	66.0	-3.			2700
HARPOON BOX/4	704	3.84	+14.	100		44
TT MK 32 TRIPLE	708	3.5	+3.			27
LAMPS HELOS (2)	805	17.86	+7.			
SRR HELO		7.	+9.7			
HH-3 HELO		9.8	+9.7			
76mm ROUND		.015				
5'/38 ROUND		.0435				
CHAFFROC		.048				
MK 48 TORPEDO		1.78				

APPENDIX B

PROGRAM LISTING

```
      REAL LEN,KGTRY,NOFF,NCPO,NENL
      REAL MCST
      COMMON/AA/ENDDAY,NOFF,NCPO,NENL
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,      SPCMHP,SPCHHP,MTYPE,JOPT
     1,MOPT,PC
      COMMON/DD/ELKW,AVGKW,ELOAD,BLOAD,PALOAD
      COMMON/EE/GR4WI(20),GR4CG(20),GR7WT(20),GR7CG(20),AMOWT(20),
     1AMOCG(20),ACWT(20),ACCG(20),          CARGOW(20),CARGOC(20)
      COMMON/FF/TITLE(5,40),HEAD(20),NOARM,NOELT
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP
      COMMON/HH/CGFUEL,CGLO,CGCREW,CGPE,CGPS,CCARGO,CGAMMO,CGAC,CACFUL
      COMMON/JJ/H,SEP,XLB,DB,AG,XF,MBLOC1,MBLOC2
      COMMON/KK/ELLD(20),DHAR(20),HLAR(20),ELD(20),DHA(20),HLA(20)
     1,GR7CST(20),GR4CST(20)
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL
      COMMON/MM/CSTG1,CSTG2,CSTG3,CSTG4,CSTG5,CSTG6,CSTG7,DCST,CCST,MCST
      COMMON/NN/ DOLHR,G1IND,G2IND,G3IND,G5IND,G6IND,TOTCST
      COMMON/QQ/XMLOC1,YMLOC1,ZMLOC1,XMLOC2,YMLOC2,ZMLOC2
      COMMON/RR/IREAD,IWRITE
      COMMON/SS/SHP(12),AKNOT(12)
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAR
      IREAD=5
      IWRITE=6
    2 READ(IREAD,124) INDEX
  124 FORMAT(I1)
      IF(INDEX.EQ.0) STOP
      READ(IREAD,123) (HEAD(I),I=1,20)
  123 FORMAT(20A4)
C     ARMAMENT, AIRCRAFT AND CARGO INPUT
      READ(IREAD,100) NOARM
  100 FORMAT(I2)
      READ(IREAD,101) ((TITLE(J,I),J=1,5),CARGOW(I),CARGOC(I),GR7WT(I),
     1GR7CG(I),AMOWT(I),AMOCG(I),ACWT(I),ACCG(I),ELLD(I),DHAR(I),
     2HLAR(I),GR7CST(I),I=1,NOARM)
  101 FORMAT(5A4,12F5.0)
```

```
C       SUMS FOR PAYLOAD DATA                                         MAIN0037
        WCARGO=0.                                                     MAIN0038
        WTG7=0.                                                       MAIN0039
        WTAMMO=0.                                                     MAIN0040
        WTAC=0.                                                       MAIN0041
        ELOAD=0.                                                      MAIN0042
        BLOAD=0.                                                      MAIN0043
        AREADH=0.                                                     MAIN0044
        AREAHL=0.                                                     MAIN0045
        CSTG7=0.                                                      MAIN0046
        DO 10 I=1,NOARM                                               MAIN0047
        WCARGO=WCARGO+CARGOW(I)                                       MAIN0048
        WTG7=WTG7+GR7WT(I)                                            MAIN0049
        WTAMMO=WTAMMO+AMOWT(I)                                        MAIN0050
        WTAC=WTAC+ACWT(I)                                             MAIN0051
        BLOAD=BLOAD+ELLD(I)                                           MAIN0052
        GR7CST(I)=GR7CST(I)*1000.                                     MAIN0053
        CSTG7=CSTG7+GR7CST(I)                                         MAIN0054
        AREADH=AREADH+DHAR(I)                                         MAIN0055
   10   AREAHL=AREAHL+HLAR(I)                                         MAIN0056
C       ELECTRONICS INPUT                                             MAIN0057
        READ(IREAD,102) NOELT                                         MAIN0058
  102   FORMAT(I2)                                                    MAIN0059
        READ(IREAD,103) ((TITLE(J,I+20),J=1,5),GR4WT(I),GR4CG(I),ELD(I),MAIN0060
       1DHA(I),HLA(I),GR4CST(I),I=1,NOELT)                            MAIN0061
  103   FORMAT(5A4,6F5.0)                                             MAIN0062
C       GROUP 4 WEIGHTS INCLUDED IN WLSHIP                            MAIN0063
C       SUM ELECTRONICS DATA                                          MAIN0064
        WTG4=0.                                                       MAIN0065
        CSTG4=0.                                                      MAIN0066
        DO 11 I=1,NOELT                                               MAIN0067
        WTG4=WTG4+GR4WT(I)                                            MAIN0068
        ELOAD=ELOAD+ELD(I)                                            MAIN0069
        GR4CST(I)=GR4CST(I)*1000.                                     MAIN0070
        CSTG4=CSTG4+GR4CST(I)                                         MAIN0071
        AREADH=AREADH+DHA(I)                                          MAIN0072
```

```
   11 AREAHL=AREAHL+HLA(I)
      G4CST=CSTG4
      G7CST=CSTG7
C     MANNING INPUT
      READ(IREAD,104) NOOFF,NOCPO,NOCREW
  104 FORMAT(3I5)
      NOFF=FLOAT(NOOFF)
      NCPO=FLOAT(NOCPO)
      NENL=FLOAT(NOCREW)
C     COST INDICES INPUT
      READ(IREAD,110) DOLHR,G1IND,G2IND,G3IND,G5IND,G6IND
  110 FORMAT(6F5.0)
C     MILITARY MISSION CONSUMABLES INPUT
      READ(IREAD,105) ENDDAY,WACFUL,CACFUL
  105 FORMAT(3F5.0)
      HPMS=0.
      GR2CST=0.
C     JOB OPTION INPUT
C     (1 COMPUTE MAX HP, 2 COMPUTE SPEED)
      READ(IREAD,106) JOPT
  106 FORMAT(I2)
      IF(JOPT.EQ.2) GOTO 1
C     VEHICLE PERFORMANCE INPUT
      READ(IREAD,107) VSUS,VEND,RGEND,PC
  107 FORMAT(2F5.0,F10.0,F5.0)
      GOTO 9
C     MACHINERY SPECIFICATIONS INPUT
    1 READ(IREAD,108) HPMS,WTG2,SFCMHP,SFCHHP,VEND,RGEND,PALOAD,PC,
     1CSTG2,WTLO,MBLOC1,XMLOC1,MBLOC2,XMLOC2,YMLOC2,ZMLOC2
  108 FORMAT(5F5.0,F10.0,4F5.0,I1,F5.0,I1,3F5.0)
      HPMS=HPMS*1000.
      CSTG2=CSTG2*1000.
      GR2CST=CSTG2
C     OPTIONS INPUT
    9 READ(IREAD,109) MTYPE,MOPT,FRSC,LEN,DBMAR
  109 FORMAT(2I2,3F5.0)
```

```
C     MTYP=1 DIESEL,MTYPE=2 DIESEL-ELECTRIC,MTYPE=3 GAS TURBINE,MTYPE=4 GT-ELEC  MAIN0109
C     MOPT=1 STEEL HULL AND BOX W/ALUM. DECKHOUSE, MOPT=2 ALL ALUMINUM SHIP      MAIN0110
      IF(MTYPE.EQ.0) GOTO 2                                                      MAIN0111
      DBMAR=1.+DBMAR                                                             MAIN0112
      CSTG2=GR2CST                                                               MAIN0113
      CSTG4=G4CST                                                                MAIN0114
      CSTG7=G7CST                                                                MAIN0115
      KGTRY=LEN/(.0036786*LEN+5.5368)                                            MAIN0116
      DPTRY=.004606265*LEN**2.427                                                MAIN0117
      CN=105.048*LEN+6.196155*LEN*LEN+.005973*LEN*LEN*LEN                        MAIN0118
      CALL XECUTE(HPMS)                                                          MAIN0119
      GO TO 9                                                                    MAIN0120
      END                                                                        MAIN0121
```

```
      SUBROUTINE XECUTE(HPMS)                                           XECU0001
      REAL LEN,KGTRY                                                    XECU0002
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN                      XECU0003
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,      SFCMHP,SFCHHP,MTYPE,JOPT XECU0004
     1,MOPT,PC                                                          XECU0005
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP                     XECU0006
      COMMON/II/JNDEX,LNDEX                                             XECU0007
      COMMON/RR/IREAD,K                                                 XECU0008
      COMMON/SS/SHP(12),AKNOT(12)                                       XECU0009
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAR  XECU0010
      DIMENSION AE(50)                                                  XECU0011
      EXCKG=0.                                                          XECU0012
      JNDEX=1                                                           XECU0013
      LNDEX=1                                                           XECU0014
    7 CALL DIM(R)                                                       XECU0015
      IF(LEN.LT.0.) GOTO 999                                            XECU0016
C     REMOVE THE FOLLOWING CARD FOR AN UNRESTRICTED RUN                 XECU0017
      IF(JNDEX.GT.5.OR.LNDEX.GT.5) GO TO 99                             XECU0018
      CALL HPCALC                                                       XECU0019
      IF(LEN.LT.0.) GOTO 998                                            XECU0020
      CALL UGLYDK(10,1,1,AKNOT,SHP,ESL,ESR,AE)                          XECU0021
      IF(JOPT.EQ.2) GOTO 1                                              XECU0022
      CALL EVALDK(10,1,AKNOT,VSUS,SHPM,AE)                              XECU0023
      CALL EVALDK(10,1,AKNOT,VEND,SHPE,AE)                              XECU0024
      SHPM=SHPM/.8                                                      XECU0025
      GO TO 99                                                          XECU0026
    1 VMAX=(HPMS*200./LEN)**.33333                                      XECU0027
    4 CALL EVALDK(10,1,AKNOT,VMAX,SHP1,AE)                              XECU0028
      VMAX1=.95*VMAX                                                    XECU0029
      CALL EVALDK(10,1,AKNOT,VMAX1,SHP2,AE)                             XECU0030
      DELHP=(SHP1-SHP2)/(VMAX-VMAX1)                                    XECU0031
      VMAX1=VMAX-(SHP1-.8*HPMS)/DELHP                                   XECU0032
      IF(ABS(VMAX1-VMAX).LE.VMAX1*.005) GOTO 3                          XECU0033
      VMAX=VMAX1                                                        XECU0034
      GOTO 4                                                            XECU0035
    3 VSUS=VMAX1                                                        XECU0036
```

```
      SHPM=HPMS                                                         XECU0037
      CALL EVALDK(10,1,AKNOT,VEND,SHPE,AE)                              XECU0038
   99 CONTINUE                                                          XECU0039
      IF(MTYPE.EQ.1) GO TO 100                                          XECU0040
      IF(MTYPE.EQ.2) GO TO 200                                          XECU0041
      IF(MTYPE.EQ.3) GO TO 300                                          XECU0042
      IF(SHPM.GT.30000..OR.DH.LT.(10.+.0003*SHPM)) GO TO 997            XECU0043
      GO TO 500                                                         XECU0044
  100 CONTINUE                                                          XECU0045
      IF(SHPM.GT.14000..OR.DH.LT.14.) GO TO 997                         XECU0046
      GO TO 500                                                         XECU0047
  200 CONTINUE                                                          XECU0048
      IF(SHPM.GT.30000..OR.DH.LT.(10.+.0003*SHPM)) GO TO 997            XECU0049
      GO TO 500                                                         XECU0050
  300 CONTINUE                                                          XECU0051
      IF(SHPM.GT.8000..AND.BS.LT.6.) GO TO 997                          XECU0052
      IF(SHPM.GT.70000.) GO TO 997                                      XECU0053
  500 CONTINUE                                                          XECU0054
      CALL EPLANT                                                       XECU0055
      CALL LIQ                                                          XECU0056
      IF(JOPT.EQ.2) GOTO 6                                              XECU0057
      CALL MACHBX                                                       XECU0058
    6 CALL VOLUME                                                       XECU0059
      IF(LEN.LT.0.) GOTO 996                                            XECU0060
      CALL WEIGHT                                                       XECU0061
      IF(ABS(WFULLD-DPTRY).LT.9.) GO TO 8                               XECU0062
      IF(LNDEX.GE.2) GOTO 9                                             XECU0063
      NHALF=1                                                           XECU0064
      FACTOR=.6                                                         XECU0065
      GO TO 63                                                          XECU0066
    9 FACTOR=(DPTRY-WFULLD-DP1+WT1)/(DPTRY-DP1)                         XECU0067
   63 DP1=DPTRY                                                         XECU0068
      WT1=WFULLD                                                        XECU0069
      DPTRY=DPTRY-(DPTRY-WFULLD)/FACTOR                                 XECU0070
      IF(FACTOR.GE.0.) GO TO 10                                         XECU0071
      IF(DPTRY.LT.0.) GO TO 60                                          XECU0072
```

```
      DPTRY=(.8**NHALF)*DP1
      GO TO 65
   60 DPTRY=(2.**NHALF)*DP1
   65 NHALF=NHALF+1
   10 IF(LNDEX.GT.20) GOTO 995
      LNDEX=LNDEX+1
      GOTO 7
    9 CONTINUE
      LNDEX=1
      CALL VCG(CFULLD)
      IF(ABS(CFULLD-KGTRY).LT.1.) GO TO 11
      IF(JNDEX.GT.21) GOTO 994
      IF(CFULLD.LT.KGTRY) GOTO 12
   13 KGTRY=(CFULLD+KGTRY)/2.
      JNDEX=JNDEX+1
      GOTO 7
   12 IF(R.LT..1) GO TO 13
      EXCKG=KGTRY-CFULLD
   11 CONTINUE
      CALL COST(LEN)
      CALL OUTPUT(EXCKG,2)
      RETURN
  994 CALL OUTPUT(0.,1)
      WRITE(K,106)
  106 FORMAT(///' NO BALANCE BETWEEN ASSUMED AND CALC KG WITHIN 1.0 FEET
     1 COULD BE MADE IN 20 ITERATIONS'///)
      GOTO 1000
  995 CALL OUTPUT(0.,1)
      WRITE(K,105)
  105 FORMAT(///' NO BALANCE BETWEEN WEIGHT AND DISPLACEMENT WITHIN 5
     1TONS COULD BE MADE IN 20 ITERATIONS'///)
      GOTO 1000
  996 CALL OUTPUT(0.,1)
      WRITE(K,104)
  104 FORMAT(///' TOO LARGE A VOLUME REQUIRED FOR SOLUTION USING INPUT
     1LENGTH, TRY A LONGER SHIP'///)
```

```
      GOTO 1000
  997 CALL OUTPUT(0.,1)
      WRITE(K,103)
  103 FORMAT(///' MACHINERY TYPE SELECTION,SHIP SIZE OR HORSEPOWER REQUI
     1REMENTS OUTSIDE MODEL LIMITS.'/' INPUT MACHINERY DATA FOR MTYPE=3
     2OR JOPT=2'///)
      GOTO 1000
  998 CALL OUTPUT(0.,1)
      WRITE(K,101)
  101 FORMAT(///' HPCALC ERROR. CHECK INPUTS'///)
      GOTO 1000
  999 CALL OUTPUT(0.,1)
      WRITE(K,1001)
 1001 FORMAT(///' SHIP PARAMETER INPUT GIVES DIMENSIONS OUT OF RANGE'/)
 1000 WRITE(K,102)
  102 FORMAT(' PROGRAM PROCEEDING TO NEXT INPUT CASE'///)
      RETURN
      END
```

```
      SUBROUTINE DIM(R)
      REAL LEN,KGTRY
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/GG/FRSC,              KGTRY,DISP,DH   ,BBOX,BSTR,STRL,CWP
      COMMON/JJ/H,SEP,XLB,DB,AG,XP,MBLOC1,MBLOC2
      DPTRY=DISP/1.014
      RLENDH=12.33+.013*LEN
C     THIS CALCULATION APPROXIMATES HULLS AS ELLIPTICAL NOSES OF LENGTH
C     3 DH, A PARALLEL MIDDLE BODY AND A CONICAL TAIL OF LENGTH 5 DH.
      DH=LEN/RLENDH
    2 VPMB=(LEN-8.*DH)*DH*DH*.785398
C     THERE WILL ALWAYS BE SOME PARALLEL MIDDLE BODY.  L/D = 10 MIN.
      IF(LEN-8.*DH.LT.2.*DH) GO TO 1000
      VAB=1.30899*DH*DH*DH
      VFB=1.57079*DH*DH*DH
      VHULS=2.*(VPMB+VAB+VFB)
      IF(VHULS/35..GT..55*DPTRY) GO TO 3
      DH=DH+.25
      GO TO 2
    3 H=1.75*DH
      VCNTS=1.6*DPTRY
C     STRUT SIZING BASED ON STABILITY REQUIREMENTS, CHECK DISPLACEMENT,
C     GML,GMT. STRUT BEAM INCREMENTED LAST FOR RESISTANCE PURPOSES
      BSTR=.42*DH
      BSTRS=4.
    6 BS=AMAX1(BSTR,BSTRS)
      CWP=.34
    9 STRL=.4*LEN
   10 VSTRTS=2.*((STRL*BS*CWP)*(H-DH)+STRL*(.5*BS*(DH-.5*DH*SQRT(1.-BS*
     1BS/(DH*DH)))-.25*DH*DH*ARSIN(BS/DH)))
      SVT= VHULS+VSTRTS+VCNTS
      DPTRY1=SVT/35.
      IF(ABS(DPTRY1-DPTRY).LE.5.) GO TO 20
      R1=STRL/LEN
      IF(R1.GE..80) GO TO 15
      STRL=STRL+1.
```

```
      GO TO 10                                                          DIM 0037
   15 CONTINUE                                                          DIM 0038
      IF(CWP.GE..94) GO TO 30                                           DIM 0039
      CWP=CWP+.002                                                      DIM 0040
      GO TO 10                                                          DIM 0041
   30 R2=BS/DH                                                          DIM 0042
      IF(R2.GT..55) GO TO 1000                                          DIM 0043
      BS=BS+.05                                                         DIM 0044
      GO TO 10                                                          DIM 0045
   20 FKB=(VHULS*DH*.5+VSTRTS*(DH+.5*(H-DH))+VCNTS*DH*.5)/SVT           DIM 0046
      FBG=KGTRY-FKB                                                     DIM 0047
      AWP=STRL*BS*CWP                                                   DIM 0048
      CIL=-4.2491+5.2141*CWP                                            DIM 0049
      GML=2.*CIL*STRL*STRL*STRL*BS/SVT-FBG                              DIM 0050
      IF(GML.GE..1*STRL) GO TO 40                                       DIM 0051
      GO TO 1000                                                        DIM 0052
   40 CONTINUE                                                          DIM 0053
C     CHANGE GMT WITH SEPARATION PARAMETER                              DIM 0054
      SEP=.22*LEN                                                       DIM 0055
      GMTT=.2*DH                                                        DIM 0056
      SEPT=.4*LEN                                                       DIM 0057
   41 GMT1=SEP*SEP*AWP/(2.*SVT)-FBG-FRSC                                DIM 0058
      IF(GMT1.GT.GMTT) GO TO 50                                         DIM 0059
      IF(SEP.GT.SEPT) GO TO 1000                                        DIM 0060
      SEP=SEP+1.                                                        DIM 0061
      GO TO 41                                                          DIM 0062
   50 CONTINUE                                                          DIM 0063
      BSTR=BS                                                           DIM 0064
      R=FKB+SEP*SEP*AWP/(2.*SVT)-FRSC-GMT1-KGTRY                        DIM 0065
C     PLACE STRUT ON HUL                                                DIM 0066
      XF=.52*LEN                                                        DIM 0067
C     SIZE BOX                                                          DIM 0068
      XLB=STRL+20.                                                      DIM 0069
      BBOX=SEP+DH                                                       DIM 0070
      DB=13.                                                            DIM 0071
      AG=1.+.07*LEN                                                     DIM 0072
```

```
      IF(LEN.GE.200.) AG=15.
      RETURN
 1000 LEN=-10.0
      RETURN
      END
```

```
      SUBROUTINE HPCALC
      REAL LEN
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,      SFCMHP,SFCHHP,MTYPE,JOPT
     1,MOPT,PC
      COMMON/GG/FRSC,KGTRY,TONS,DH,BBOX,TA,CA,CWP
      COMMON/JJ/H,SEP,XLB,DB,AG,XA,MBLOC1,MBLOC2
      COMMON/SS/POW(12),VKNTS(12)
      DOUBLE PRECISION BN,BT,QN,QT
C  INPUT SHIP CHARACTERISTICS
C  L = NUMBER OF HULL SEGMENTS +2, NOT COUNTING THE NOSE AND TAIL.
C     THERE WILL BE NO CONTROL SURFACES IN THIS CALCULATION
C     THIS CALCULATION ASSUMES ELLIPTICAL NOSES AND PARABOLIC TAILS ON
C     THE HULLS AND FULLY PARABOLIC STRUTS WITH NO TAPER.  ONLY ONE STRUT
C     AND TWO HULL CASES ARE ALLOWED.  THE LENGTHS OF THE NOSES AND TAILS
C     ARE TAKEN AS 3 TIMES DH AND 5 TIMES DH RESPECTIVELY.
      VOL=0.0
      AREAH=0.0
      PI = 3.1415926536
      YA=3.*TA
      EA=CA-8.*TA
      DELT=0.
      W=8.*LEN
      EFHG=DB
      F=H-0.5*DH
C  AN = LENGTH OF NOSE SECTION
C  AT = LENGTH OF TAIL SECTION
      AN=3.*DH
      AT=5.*DH
C     WETTED SURFACE AREA AND VOLUME OF TAILS
C  VOLT = VOLUME OF A SINGLE TAIL SECTION
C  VOLT2 = VOLUME OF BOTH TAIL SECTIONS
C  ARET = WETTED SURFACE AREA OF A SINGLE TAIL SECTION
C  ARET2 = WETTED SURFACE AREA OF BOTH TAIL SECTIONS
C  PARABOLIC TAIL
   66 ARET=0.66666*PI*AT*DH
```

```
      VOLT=2.0/15.0*PI*AT*DH*DH                                         HPCL0037
   67 CONTINUE                                                          HPCL0038
      VOLT2 = 2.0*VOLT                                                  HPCL0039
      ARET2 = 2.0*ARET                                                  HPCL0040
C     WETTED SURFACE AREA AND VOLUME OF HULLS                           HPCL0041
C  VH = VOLUME OF A SINGLE HULL SEGMENT                                 HPCL0042
C  VOLH = VOLUME OF A SINGLE HULL, NO NOSE OR TAIL.                     HPCL0043
C  VOLH2 = VOLUME OF BOTH HULLS, NO NOSE OR TAIL SECTIONS               HPCL0044
C  AH = AREA OF A SINGLE HULL SEGMENT.                                  HPCL0045
C  AREH = AREA OF A SINGLE HULL, NO NOSE OR TAIL.                       HPCL0046
C  AREH2 = AREA OF BOTH HULLS, NO NOSE OR TAIL SECTIONS                 HPCL0047
C  SL = HULL SEGMENT LENGTH                                             HPCL0048
      SL=LEN-8.*DH                                                      HPCL0049
      IF(SL.GT.0.0) GO TO 68                                            HPCL0050
      GO TO 1000                                                        HPCL0051
   68 VOLH=PI/4.*(DH*DH*SL)                                             HPCL0052
      AREH=PI*DH*SL                                                     HPCL0053
      VOLH2 = 2.0*VOLH                                                  HPCL0054
      AREH2 = 2.0*AREH                                                  HPCL0055
C     WETTED SURFACE AREA AND VOLUME OF NOSES                           HPCL0056
C  VOLN = VOLUME OF SINGLE NOSE SECTION                                 HPCL0057
C  VOLN2 = VOLUME OF BOTH NOSE SECTIONS                                 HPCL0058
C  AREN = SURFACE AREA OF SINGLE NOSE SECTION                           HPCL0059
C  AREN2 = AREA OF BOTH NOSE SECTIONS                                   HPCL0060
C  PROLATED SPHEROID                                                    HPCL0061
   50 EN= SQRT(1.0-DH*DH*0.25/(AN*AN))                                  HPCL0062
      AREN=PI*DH*(DH/4.+AN/2./EN*ARSIN(EN))                             HPCL0063
      VOLN=PI/6.0*AN*DH**2                                              HPCL0064
      VOLN2 = 2.0*VOLN                                                  HPCL0065
      AREN2 = 2.0*AREN                                                  HPCL0066
C  VOLHT = TOTAL VOLUME OF SINGLE HULL WITH NOSE AND TAIL SECTIONS.     HPCL0067
C  VOLHT2 = TOTAL VOLUME OF BOTH HULLS WITH NOSE AND TAIL SECTIONS.     HPCL0068
      VOLHT = VOLN+VOLT+VOLH                                            HPCL0069
      VOLHT2 = 2.0*VOLHT                                                HPCL0070
C     WETTED SURFACE AREA AND VOLUME OF STRUTS                          HPCL0071
C  VOLAS = VOLUME OF AFT STRUT                                          HPCL0072
```

```
C  CA = CHORD OF AFT STRUT
C  YA = LENGTH OF AFT STRUT NOSE
C  EA = LENGTH OF AFT STRUT CENTER SECTION
C  WA = LENGTH OF AFT STRUT TAIL
C  XAT = DISTANCE TO REAR OF AFT STRUT
C  XATC = DISTANCE TO FRONT OF AFT STRUT TAIL
C  XA = DISTANCE TO CENTER OF AFT STRUT
C  XANC = DISTANCE TO REAR OF AFT STRUT NOSE
C  XAN = DISTANCE TO FRONT OF AFT STRUT
C  DELT = PERCENT CHANGE IN THICKNESS OF STRUT (+ OR -) IN FEET PER FOOT DEPTH
C  TA = THICKNESS OF CENTER OF AFT STRUT AT WATERLINE
C  F = DEPTH OF HULL CENTERLINE
C  TX = THICKNESS AT ARBITRARY POSITION IN STRUT AT WATERLINE.
C  TZ = THICKNESS OF STRUT AT THE POSITION OF TX AND DEPTH Z.
      VOLAS = 0.0
      DELA = 0.0
      ASIA = 0.0
      WA = CA-YA-EA
      XAT = XA-CA/2.0
      XAN = XA+CA/2.0
      XANC = XAN-YA
      XATC = XAT+WA
      NFLAG = 0
      IFLAG = 0
C  XS = ARBITRARY LENGTH POSITION FOR VOLUME INTEGRATION
C  DEL = INCREMENTAL LENGTH THAT STRUT IS DEVIDED INTO FOR FOLLOWING ITERATION
      DEL = CA/500.0
      XS = XAT
      DO 500 M = 1,501
      IF(XS.LT.XATC) GO TO 501
      IF(XS.LT.XANC) GO TO 502
C  CALCULATE POSITION IN STRUT NOSE AND THICKNESS AT WATERLINE
      XSS = XS-XANC
C  TX FOR PARABOLIC NOSE
      TX = TA*(1.0-(XSS/YA)**2)
      GO TO 503
```

```
     1ZA**2)
C  MAKE COMPUTATIONS AND ADDITIONS FOR NATURAL STRUT HULL INTERSECTION
      TTD = TZ/DIA
      THETA=ARSIN(TTD)
      DDZ = 0.5*DIA*(1.0-SQRT(1.0-TTD*TTD))
      ASIA = ASIA+DIA*THETA*SQRT(((DIA-DIA1)/2.0)**2+DEL**2)
      VOLAS = VOLAS+(TZ*(DDZ+DIA/2.0)/2.0-(THETA*DIA**2)/4.0)*DEL
      DELA = DELA+DDZ*SQRT(((TX-TX1)/2.0)**2+DEL**2)
      GO TO 506
  506 DIA1 = DIA
      TX1 = TX
      Z1 = Z
C  VOLAST = VOLUME OF AFT STRUT TAIL
C  VOLASC = VOLUME OF AFT STRUT CENTER SECTION
C  VOLASN = VOLUME OF AFT STRUT NOSE
      IF(XS.LT.XATC) GO TO 499
      IF(NFLAG.EQ.0) VOLAST = VOLAS
      NFLAG = 1
      IF(XS.LT.XANC) GO TO 499
      IF(IFLAG.EQ.0) VOLASC = VOLAS-VOLAST
      IFLAG = 1
  499 XS = XS+DEL
  500 CONTINUE
      VOLASN = VOLAS-VOLASC-VOLAST
C  AREAS = WETTED SURFACE AREA OF SINGLE AFT STRUT
C  AREAS2 = WETTED SURFACE AREA OF BOTH AFT STRUTS
      AREAS = 2.0*DELA
      AREAS2 = 2.0*AREAS
C  IF SINGLE STRUT CONFIGURATION, SET FORWARD STRUT VALUES TO 0.0
  110 VOLFS = 0.0
      FSIA = 0.0
      DELF = 0.0
      VOLFST = 0.0
      VOLFSC = 0.0
      VOLFSN = 0.0
      CF=0.
```

```
C  AREFS = WETTED SURFACE AREA OF SINGLE FORWARD STRUT                    HPCL0181
C  AREFS2 = WETTED SURFACE AREA OF BOTH FORWARD STRUTS                    HPCL0182
  111 AREFS = 2.0*DELF                                                    HPCL0183
      AREFS2 = 2.0*AREFS                                                  HPCL0184
C  VOLFS2 = VOLUME OF BOTH FORWARD STRUTS                                 HPCL0185
C  VOLAS2 = VOLUME OF BOTH AFT STRUTS                                     HPCL0186
      VOLFS2 = 2.0*VOLFS                                                  HPCL0187
      VOLAS2 = 2.0*VOLAS                                                  HPCL0188
C  WPLA = INTERSECTION AREA OF SINGLE HULL AND STRUTS                     HPCL0189
C  WPLA2 = INTERSECTION AREA OF BOTH HULLS AND STRUTS                     HPCL0190
      WPLA = ASIA+FSIA                                                    HPCL0191
      WPLA2 = 2.0*WPLA                                                    HPCL0192
C                         ***   MEAN STRUT DEPTHS   ***                   HPCL0193
C  ZAT,ZAC,ZAN ARE MEAN DEPTHS OF AFT STRUT TAIL,CENTER,AND NOSE SECTION  HPCL0194
  457 ZAT=  1.5*VOLAST/(WA*TA)                                            HPCL0195
      ZAN=  1.5*VOLASN/(YA*TA)                                            HPCL0196
C IF NO  CENTER SECTION SET ZAC                                           HPCL0197
      ZAC= ZAT                                                            HPCL0198
      IF(ABS(EA).GE.0.0001*CA)  ZAC=VOLASC/(EA*TA)                        HPCL0199
  459 AREAF = 0.0                                                         HPCL0200
      AREAF2 = 0.0                                                        HPCL0201
      AREFF = 0.0                                                         HPCL0202
      AREFF2 = 0.0                                                        HPCL0203
      VOLAF = 0.0                                                         HPCL0204
      VOLAF2 = 0.0                                                        HPCL0205
      VOLFF = 0.0                                                         HPCL0206
      VOLFF2 = 0.0                                                        HPCL0207
      WAF = 0.0                                                           HPCL0208
      CFINF=0.                                                            HPCL0209
      CFINA=0.                                                            HPCL0210
C  ARUD = WETTED SURFACE AREA OF SINGLE RUDDER                            HPCL0211
C  APGD = WETTED SURFACE AREA OF SINGLE PROP GUARD                        HPCL0212
  460 ARUD=0.                                                             HPCL0213
      APGD=0.                                                             HPCL0214
C  VOL = TOTAL VOLUME OF ALL SUBMERGED PARTS FOR SINGLE HULL              HPCL0215
C  VOL2 = TOTAL VOLUME OF ALL SUBMERGED PARTS FOR DUAL HULL               HPCL0216
```

```
      VOL = VOLT+VOLN+VOLH+VOLFS+VOLAS+VOLFF+VOLAF                      HPCL0217
      VOL2 = 2.0*VOL                                                    HPCL0218
C  AREAH = TOTAL WETTED AREA OF SINGLE HULL WITH NOSE AND TAIL SECTIONS HPCL0219
C  MINUS INTERSECTION AREA OF STRUTS AND FINS                           HPCL0220
C  AREAH2 = TOTAL WETTED SURFACE AREA OF BOTH HULLS WITH NOSE AND TAIL SECTIONS HPCL0221
C  MINUS INTERSECTION AREA OF ALL STRUTS AND FINS                       HPCL0222
      AREAH = AREN+AREI+AREH-WAF-WPLA                                   HPCL0223
      AREAH2 = 2.0*AREAH                                                HPCL0224
C  AREAT = TOTAL WETTED SURFACE AREA FOR SINGLE HULL                    HPCL0225
C  AREAT2 = TOTAL WETTED SURFACE AREA FOR DUAL HULL                     HPCL0226
      AREAT = AREAH+AREFS+AREAS+AREFF+AREAF+ARUD+APGD                   HPCL0227
      AREAT2 = 2.0*AREAT                                                HPCL0228
C  TONS = TONNAGE OF VESSEL                                             HPCL0229
      TONS=VOL/17.5                                                     HPCL0230
  192 AREA=AREAT*2.                                                     HPCL0231
C                           *** WIND DRAG COEFFICIENT ***               HPCL0232
C  RHO=DENSITY                                                          HPCL0233
      RHO= 1.9905                                                       HPCL0234
C  RWN = WIND DRAG COEFFICIENT                                          HPCL0235
   80 RWN = 0.00115*EFHG*SEP/(RHO*AREA)                                 HPCL0236
   84 DIL = 0.0                                                         HPCL0237
C  THICKNESS TO CHORD RATIOS OF FWD AND AFT STRUTS AND FINS             HPCL0238
   85 TOCA = TA*(1.0+DELT*0.25*(ZAT+ZAN))/CA                            HPCL0239
      TOCF = 0.0                                                        HPCL0240
      TOC3 = 0.0                                                        HPCL0241
      TOC4 = 0.0                                                        HPCL0242
C  EDDY MAKING RESISTANCE FACTORS FOR STRUTS AND FINS                   HPCL0243
C  SDF = EDDY MAKING RESISTANCE FACTOR FOR FORWARD STRUT                HPCL0244
C  SDA = EDDY MAKING RESISTANCE FACTOR FOR AFT STRUT                    HPCL0245
C  SD3 = EDDY MAKING RESISTANCE FACTOR FOR FORWARD FIN                  HPCL0246
C  SD4 = EDDY MAKING RESISTANCE FACTOR FOR AFT FIN                      HPCL0247
      SDA=1.0+TOCA+TOCA+60.0*TOCA*TOCA*TOCA*TOCA                        HPCL0248
      SDF=0.                                                            HPCL0249
C                           ***  VELOCITY GENERATION  ***               HPCL0250
C  CONSTANTS USED WITHIN LOOP                                           HPCL0251
C  VISC=VISCOSITY                                                       HPCL0252
```

```
      VISC=.00001279
      BACT =32.0*3.14159*3.14159 /(W*AREA)
      I=10
      DELTA=3.
      SPEED=6.
      DO 400 K=1,I
      IF(K.NE.1) SPEED=SPEED+DELTA
      FPS=SPEED*1.6788
C     SPEED IS SPEED IN KNOTS
C     VKNTS IS SPEED IN KNOTS
C  FPS IS SPEED IN FEET PER SECOND
C                        *** WAVEMAKING RESISTANCE ***
C  AK = EQUATION CONSTANT
C  BACT = EQUATION CONSTANT
      AK= 32.1725/(FPS*FPS)
      FACT =BACT*AK
C  INITIALIZE WAVE-DRAG COEFFICIENTS AT ZERO FOR FOLLOWING SUMMATION
C  WRSTF = WAVE-DRAG COEFFICIENT OF FORWARD STRUTS ONLY
C  WRSTA = WAVE-DRAG COEFFICIENT OF AFT STRUTS ONLY
C  WRST = WAVE-DRAG COEFFICIENT OF ALL STRUTS AND STRUT INTERFERENCE, NO HULL
C  WRHL = WAVE-DRAG COEFFICIENT OF HULL ALONE
C  WWA = WAVE-DRAG COEFFICIENT OF HULL AND AFT STRUT INTERFERENCE
C  WWF = WAVE-DRAG COEFFICIENT OF HULL AND FORWARD STRUT INTERFERENCE
C  R = TOTAL WAVE-DRAG COEFFICIENT
      WRSTF = 0.0
      WRSTA = 0.0
      WRST = 0.0
      WRHL = 0.0
      WWF = 0.0
      WWA = 0.0
      R = 0.0
C  ALL = MULTIPLICATION FACTOR IN FOLLOWING ITERATION
C  ALL IS 1.0 FOR FIRST ITERATION TERM AND 2.0 FOR ALL OTHERS
      ALL = 1.0
C  START WAVEMAKING SUMMATION, CONSISTS OF 400 TERMS
      DO 401 K2=1,400
```

```
C  COMPUTE HYPERBOLIC FUNCTIONS                                               HPCL0289
C  G = SINH(2X)                                                               HPCL0290
C  CH2 = COSH(2X)                                                             HPCL0291
C  CH = COSH(X)                                                               HPCL0292
C  SH = SINH(X)                                                               HPCL0293
C  SQ INDICATES SQUARED TERM                                                  HPCL0294
      G=4.0*3.14159*FLOAT(K2-1)/(AK*W)                                        HPCL0295
      CH2=  SQRT(1.0+G*G)                                                     HPCL0296
      CHSQ =0.5*(CH2+1.0)                                                     HPCL0297
      CH= SQRT(CHSQ)                                                          HPCL0298
      SH= SQRT(CHSQ-1.0)                                                      HPCL0299
C  FA = MULTIPLICATION FACTOR IN ITERATION                                    HPCL0300
      FA = FACT*CHSQ*ALL/CH2                                                  HPCL0301
      ALL = 2.0                                                               HPCL0302
      AM = CH*AK                                                              HPCL0303
      BT=CH*AM                                                                HPCL0304
C  IF TWO  HULLS INCLUDE WAVEMAKING INTERFERENCE FACTOR                       HPCL0305
      FA=FA*(1.0+DCOS(DBLE(AK*SEP*CH*SH)))*2.                                 HPCL0306
C  ************     WAVEMAKING  - AFT  STRUT          *************           HPCL0307
C STRUT DEPTH FACTORS                                                         HPCL0308
      UAT=EXP(SNGL(-BT*ZAT))                                                  HPCL0309
      UAC=EXP(SNGL(-BT*ZAC))                                                  HPCL0310
      UAN=EXP(SNGL(-BT*ZAN))                                                  HPCL0311
      VAT= TA*(1.-UAT+DELT*ZAT*(1.-(1.+BT*ZAT)*UAT)/(BT*ZAT))/(PI*BT)         HPCL0312
      VAN= TA*(1.-UAN+DELT*ZAN*(1.-(1.+BT*ZAN)*UAN)/(BT*ZAN))/(PI*BT)         HPCL0313
      VAC= TA*(1.-UAC+DELT*ZAC*(1.-(1.+BT*ZAC)*UAC)/(BT*ZAC))/(PI*BT*4.0      HPCL0314
     1)                                                                       HPCL0315
C NORMALIZED STRUT SEGMENT LENGTHS                                            HPCL0316
      QAN= YA*AM                                                              HPCL0317
      QAC= EA*AM*0.5                                                          HPCL0318
      QAT= WA*AM                                                              HPCL0319
C I AND J FUNCTIONS FOR PARABOLIC  AFT STRUT TAIL SECTION  ASSUMING XATC= ZERO  HPCL0320
      BIAT=-0.5*(COS(QAT)+QAT*SIN(QAT)-1.0)*VAT/(QAT*QAT)                     HPCL0321
      BJAT= 0.5*(SIN(QAT)-QAT*COS(QAT))*VAT/(QAT*QAT)                         HPCL0322
C I AND J FOR PARABOLIC AFT STRUT NOSE SECTION   ASSUMING  XANC=ZERO          HPCL0323
      BJAN = 0.5*(SIN(QAN)-QAN*COS(QAN))*VAN/(QAN*QAN)                        HPCL0324
```

```
      BIAN = 0.5*(COS(QAN)+QAN*SIN(QAN)-1.0)*VAN/(QAN*QAN)                HPCL0325
      GO  TO  981                                                          HPCL0326
C ADD CENTER SECTION TO STRUT FOR TOTAL I ANDJ  FOR XA=ZERO                 HPCL0327
  981 BJA=SIN(QAC)*(BIAN-BIAT+VAC+VAC-.25*(VAT+VAN))+COS(QAC)*(BJAN+BJAT   HPCL0328
     1)                                                                    HPCL0329
      BIA=COS(QAC)*(BIAN+BIAT+0.25*(VAT-VAN))-SIN(QAC)*(BJAN-BJAT)         HPCL0330
C TRANSLATE STRUT TO PROPER LOCATION FOR XA                                HPCL0331
      BA= XA*AM                                                            HPCL0332
      AIA= -BJA*SIN(BA)  +  BIA*COS(BA)                                    HPCL0333
      AJA=  BJA*COS(BA)  +  BIA*SIN(BA)                                    HPCL0334
C  CALCULATIONS FOR ELLIPSOIDAL NOSE AND TAIL SECTIONS FOR XN AND XT BOTH ZERO  HPCL0335
C  BIN, BJN, BIT, AND BJT ARE I AND J TERMS FOR NOSE AND TAIL               HPCL0336
C  B COEFFICIENT IMPLIES NON TRANSLATED VALUE                               HPCL0337
C  A COEFFICIENT IMPLIES TRANSLATED VALUE                                   HPCL0338
C NONDIMENSIONAL HULL NOSE AND TAIL SECTION LENGTHS                         HPCL0339
      QN=AN*AM                                                             HPCL0340
      QT=AT*AM                                                             HPCL0341
C HULL  WAVEMAKING DEPTH FACTOR                                            HPCL0342
      ABB=  EXP(-F*AM*AM/AK)/16.0                                          HPCL0343
      AAA=  ABB*2.0/(AM*AM)                                                HPCL0344
      BIN = AAA*(DCOS(QN)+QN*DSIN(QN)-1.0)/(AN*AN)                         HPCL0345
      BIT =-AAA*(DCOS(QT)+QT*DSIN(QT)-1.C)/(AT*AT)                         HPCL0346
      BJN=AAA*(DSIN(QN)-QN*DCOS(QN))/(AN*AN)                               HPCL0347
      BJT=AAA*(DSIN(QT)-QT*DCOS(QT))/(AT*AT)                               HPCL0348
C  CORRECTION OF BIT, BJT FOR PARABOLIC TAIL                               HPCL0349
      AZ=12.0*AAA/(AM*AM*AT*AT*AT*AT)                                      HPCL0350
C  USE EXPANSION FOR SMALL VALUES OF QT FOR NUMERICAL ACCURACTY, USE TRIG  HPCL0351
C  TERMS FOR LARGER VALUES                                                 HPCL0352
      IF(QT.LT.0.05) GO TO 8744                                            HPCL0353
      BBB=AZ*(1.-DCOS(QT)*(1.-QT*QT/2.)-DSIN(QT)*QT*(1.-QT*QT/6.0))        HPCL0354
      BIT=BIT+BIT+BBB                                                      HPCL0355
      BJT=BJT*2.+AZ*(DSIN(QT)*(1.-QT*QT/2.)-QT*DCOS(QT)*(1.-QT*QT/6.))     HPCL0356
      GO  TO  7744                                                         HPCL0357
 8744 BIT =BIT*2.0 +AZ*QT*QT*QT*QT/24.0                                    HPCL0358
      BJT =BJT*2.0 +AZ*QT*QT*QT*QT*QT/(-30.0)                              HPCL0359
 7744 CONTINUE                                                             HPCL0360
```

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C  TRANSLATE NOSE AND TAIL TO PROPER LOCATIONS                      HPCL0361
 7745 BN=(LEN-3.*DH)*AM                                              HPCL0362
      BT=5.*DH*AM                                                    HPCL0363
C  REAL AND IMIGINARY CONTRIBUTIONS FROM NOSE AND TAIL               HPCL0364
      AIN=-BJN*DSIN(BN)+ BIN*DCOS(BN)                                HPCL0365
      AJN =BJN*DCOS(BN)+ BIN*DSIN(BN)                                HPCL0366
      AIT=-BJT*DSIN(BT)+ BIT*DCOS(BT)                                HPCL0367
      AJT= BJT*DCOS(BT)+ BIT*DSIN(BT)                                HPCL0368
C ADJUST I AND J FOR NOSE AND TAIL DIAMETERS                         HPCL0369
      AIN=AIN*DH*DH                                                  HPCL0370
      AJN=AJN*DH*DH                                                  HPCL0371
      AIT=AIT*DH*DH                                                  HPCL0372
      AJT=AJT*DH*DH                                                  HPCL0373
C  INITIALIZE HULL I AND J FUNCTIONS WITH NOSE AND TAIL VALUES       HPCL0374
      AIH= AIN +AIT                                                  HPCL0375
      AJH= AJN +AJT                                                  HPCL0376
      AJF=0.                                                         HPCL0377
      AIF=0.                                                         HPCL0378
      WRST=WRST+FA*((AJA+AJF)**2+(AIF+AIA)**2)                       HPCL0379
      WRSTA=WRSTA+FA*(AJA*AJA+AIA*AIA)                               HPCL0380
      WRSTF=WRSTF+FA*(AJF*AJF+AIF*AIF)                               HPCL0381
      WWA= WWA+2.0*FA*(AIH*AIA +AJH*AJA)                             HPCL0382
      WWF= WWF+2.0*FA*(AIH*AIF +AJH*AJF)                             HPCL0383
      WRHL= WRHL+(AJH**2+AIH**2)*FA                                  HPCL0384
  401 R= R+((AJA+AJF+AJH)**2+(AIA+AIF+AIH)**2)*FA                    HPCL0385
C                          *** FRICTIONAL RESISTANCE ***             HPCL0386
C  CALCULATE REYNOLDS NUMBERS                                        HPCL0387
C  REF = REYNOLDS NUMBER OF FORWARD STRUT                            HPCL0388
C  REA = REYNOLDS NUMBER OF AFT STRUT                                HPCL0389
C  REH = REYNOLDS NUMBER OF HULL                                     HPCL0390
C  REFNA = REYNOLDS NUMBER OF AFT FIN                                HPCL0391
C  REFNF = REYNOLDS NUMBER OF FORWARD FIN                            HPCL0392
      REF = FPS*CF/VISC                                              HPCL0393
      REA= FPS*CA/VISC                                               HPCL0394
      REH=FPS*LEN/VISC                                               HPCL0395
      REFNF = FPS*CFINF/VISC                                         HPCL0396
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```
      REFNA = FPS*CFINA/VISC
      IF(REF.LT.100.0) REF = 100.0
      IF(REA.LT.100.0) REA = 100.0
      IF(REH.LT.100.0) REH = 100.0
      IF(REFNF.LT.100.0) REFNF = 100.0
      IF(REFNA.LT.100.0) REFNA = 100.0
C  INITIAL GUESSES OF COEFFICIENT OF FRICTION FOR FOLLOWING ITERATION
      CFF=.003
      CFA=.003
      CFH=.003
      EFINF = .003
      EFINA = .003
C  ITERATE FOR FRICTIONAL DRAG COEFFICIENT, CALCULATE SCHOENHERR VALUES
      DO 90 K3=1,15
      CFF=(.242/DLOG10(DBLE(REF*CFF)))**2
      CFA=(.242/DLOG10(DBLE(REA*CFA)))**2
      EFINF=(.242/DLOG10(DBLE(REFNF*EFINF)))**2
      EFINA=(.242/DLOG10(DBLE(REFNA*EFINA)))**2
   90 CFH=(.242/DLOG10(DBLE(REH*CFH)))**2
C  ADD 0.0005 TO SCHOENERR VALUES
      CFF=(CFF+.0005)/AREA
      CFA =(CFA +.0005)/AREA
      CFH =(CFH +.0005)/AREA
      EFINA =(EFINA+.0004)/AREA
      EFINF =(EFINF+.0004)/AREA
C  RVF = FRICTIONAL DRAG OF FORWARD STRUTS
C  RVA = FRICTIONAL DRAG OF AFT STRUTS
C  RVH = FRICTIONAL DRAG OF HULL
C  RVFNF = FRICTIONAL DRAG OF FORWARD FINS
C  RVFNA = FRICTIONAL DRAG OF AFT FINS
C  RVRUD = FRICTIONAL DRAG OF RUDDER
C  RVPGD = FRICTIONAL DRAG OF PROP GUARD
C  RFE = TOTAL FRICTIONAL DRAG
      RVF = CFF*SDF*AREFS
      RVA = CFA*SDA*AREAS
C  RVH ACCORDING TO NAVSEC IS
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      RVH = CFH*AREAH                                                   HPCL0433
C  INCREASE HULL FRICTION DRAG BY 10 PERCENT TO ACCOUNT FOR EDDY MAKING DRAG    HPCL0434
      RVH = RVH*1.10                                                    HPCL0435
      RVFNF=0.                                                          HPCL0436
      RVFNA=0.                                                          HPCL0437
      RVRUD = ARUD*CFA                                                  HPCL0438
      RVPGD = APGD*EFINF                                                HPCL0439
      RVF = 2.0*RVF                                                     HPCL0440
      RVA = 2.0*RVA                                                     HPCL0441
      RVH = 2.0*RVH                                                     HPCL0442
      RVFNF = 2.0*RVFNF                                                 HPCL0443
      RVFNA = 2.0*RVFNA                                                 HPCL0444
      RVRUD = 2.0*RVRUD                                                 HPCL0445
      RVPGD = 2.0*RVPGD                                                 HPCL0446
   30 RFE = RVF+RVA+RVH+RVFNA+RVFNF+RVRUD+RVPGD                         HPCL0447
C                          *** SPRAY DRAG RESISTANCE ***                HPCL0448
      RSPR = 0.0                                                        HPCL0449
      RSPRR = 0.0                                                       HPCL0450
C  TSPA = FROUDE NUMBER OF AFT STRUTS                                   HPCL0451
      TSPA=FPS/SQRT(CA-EA)                                              HPCL0452
C  IF FROUDE NUMBER IS NOT SUFFICIENTLY LARGE THEN NO SPRAY DRAG        HPCL0453
 4010 IF(TSPA.LT.5.7)  GO TO 4011                                       HPCL0454
C  RSPRR = SPRAY DRAG OF AFT STRUT                                      HPCL0455
      RSPRR=  (0.011*CA*TA+0.08*TA*TA)*CFA/.004                         HPCL0456
C  CORRECTION FOR UNDER DEVELOPED SPRAY DRAG                            HPCL0457
      IF(TSPA.LT.13.0) RSPRR = RSPRR*(TSPA-5.7)/7.3                     HPCL0458
C  RSPRT = TOTAL SPRAY DRAG                                             HPCL0459
 4011 RSPRT = RSPR+RSPRR                                                HPCL0460
      RSPRT=2.*RSPRT                                                    HPCL0461
C                          ***        TOTAL DRAG       ***              HPCL0462
C  RR = TOTAL DRAG COEFFICIENT                                          HPCL0463
      RR = RFE+R+RSPRT+RWN+DIL                                          HPCL0464
C     ADD 6 PERCENT APPENDAGE RESISTANCE                                HPCL0465
      RR = RR*1.06                                                      HPCL0466
      VKNTS(K)=SPEED                                                    HPCL0467
      POW(K)=RR*AREA*RHO*FPS*FPS*0.5*FPS/(550.*PC)                      HPCL0468
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```
  400 CONTINUE                                                          HPCL0469
      RETURN                                                            HPCL0470
 1000 LEN=-10.0                                                         HPCL0471
      RETURN                                                            HPCL0472
      END                                                               HPCL0473
```

```
      SUBROUTINE UGLYDK(NIN,NCL,NCR,XIN,YIN,ESL,ESR,AE)                 UGLD0001
C     APRIL 1975 DUCK SRIES     J.E.KERWIN                              UGLD0002
      DIMENSION XIN(1),YIN(1),AE(1),H(30),D(30),A(900),S(30)            UGLD0003
      DATA HALF/0.5E00/,TWO/2.0E00/,SIX/6.0E00/,RAD/1.745329E-02/       UGLD0004
      NM1=NIN-1                                                         UGLD0005
      NM2=NM1-1                                                         UGLD0006
      NM3=NM2-1                                                         UGLD0007
      NEO=NM2                                                           UGLD0008
      DO 1 N=1,NM1                                                      UGLD0009
      H(N)=XIN(N+1)-XIN(N)                                              UGLD0010
    1 D(N)=(YIN(N+1)-YIN(N))/H(N)                                       UGLD0011
      IF(NCL.EQ.2) NEQ=NEQ+1                                            UGLD0012
      IF(NCR.EQ.2) NEQ=NEQ+1                                            UGLD0013
      NSQ=NEQ**2                                                        UGLD0014
      DO 4 N=1,NSQ                                                      UGLD0015
    4 A(N)=0.0                                                          UGLD0016
      J=1                                                               UGLD0017
      L=1                                                               UGLD0018
      IF(NCL.LT.2) GO TO 6                                              UGLD0019
      A(1)=TWO*H(1)                                                     UGLD0020
      A(2)=H(1)                                                         UGLD0021
      SLP=ESL*RAD                                                       UGLD0022
      S(1)=(D(1)-TAN(SLP))*SIX                                          UGLD0023
      J=J+1                                                             UGLD0024
      L=L+NEQ+1                                                         UGLD0025
      A(L-1)=H(1)                                                       UGLD0026
    6 DO 5 N=1,NM2                                                      UGLD0027
      IF(N.GT.1) A(L-1)=H(N)                                            UGLD0028
      A(L)=TWO*(H(N)+H(N+1))                                            UGLD0029
      IF(N.LT.NM2) A(L+1)=H(N+1)                                        UGLD0030
      IF(N.EQ.2.AND.NCL.EQ.1) A(L-1)=A(L-1)-H(N)**2/H(N+1)              UGLD0031
      IF(N.EQ.1.AND.NCL.EQ.1) A(L)=A(L)+(1.0+H(N)/H(N+1))*H(N)          UGLD0032
      IF(N.EQ.NM2.AND.NCR.EQ.1) A(L)=A(L)+(1.0+H(N+1)/H(N))*H(N+1)      UGLD0033
      IF(N.EQ.NM3.AND.NCR.EQ.1) A(L+1)=A(L+1)-H(N+2)**2/H(N+1)          UGLD0034
      S(J)=(D(N+1)-D(N))*SIX                                            UGLD0035
      J=J+1                                                             UGLD0036
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```
5     L=L+NEQ+1                                                    UGLD0037
      IF(NCR.LT.2) GO TO 7                                         UGLD0038
      A(L-1)=H(NM1)                                                UGLD0039
      A(L)=-TWO*H(NM1)                                             UGLD0040
      L=L-NEQ                                                      UGLD0041
      A(L)=-H(NM1)                                                 UGLD0042
      SLP=ESR*RAD                                                  UGLD0043
      S(J)=(D(NM1)+TAN(SLP))*SIX                                   UGLD0044
7     CALL SIMQ(A,S,NEQ,KERROR)                                    UGLD0045
      HOLD=S(NEQ)                                                  UGLD0046
      IF(NCL.EQ.2) GO TO 8                                         UGLD0047
      DO 9 N=1,NM2                                                 UGLD0048
      M=NM2-N+2                                                    UGLD0049
9     S(M)=S(M-1)                                                  UGLD0050
      IF(NCL.EQ.0) S(1)=0.0                                        UGLD0051
      BUG=H(1)/H(2)                                                UGLD0052
      IF(NCL.EQ.1) S(1)=(1.0+BUG)*S(2)-BUG*S(3)                    UGLD0053
8     IF(NCR.EQ.0) S(NIN)=0.0                                      UGLD0054
      BUG=H(NM1)/H(NM2)                                            UGLD0055
      IF(NCR.EQ.1) S(NIN)=(1.0+BUG)*S(NM1)-BUG*S(NM2)              UGLD0056
      IF(NCR.EQ.2) S(NIN)=HOLD                                     UGLD0057
      DO 10 N=1,NM1                                                UGLD0058
      AE(N)=(S(N+1)-S(N))/(SIX*H(N))                               UGLD0059
      M=N+NM1                                                      UGLD0060
      AE(M)=HALF*S(N)                                              UGLD0061
      M=M+NM1                                                      UGLD0062
      AE(M)=D(N)-H(N)*(TWO*S(N)+S(N+1))/SIX                        UGLD0063
      M=M+NM1                                                      UGLD0064
10    AE(M)=YIN(N)                                                 UGLD0065
      RETURN                                                       UGLD0066
      END                                                          UGLD0067
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```
5     L=L+NEQ+1                                          UGLD0037
      IF(NCR.LT.2) GO TO 7                               UGLD0038
      A(L-1)=H(NM1)                                      UGLD0039
      A(L)=-TWO*H(NM1)                                   UGLD0040
      L=L-NEQ                                            UGLD0041
      A(L)=-H(NM1)                                       UGLD0042
      SLP=ESR*RAD                                        UGLD0043
      S(J)=(D(NM1)+TAN(SLP))*SIX                         UGLD0044
7     CALL SIMQ(A,S,NEQ,KERROR)                          UGLD0045
      HOLD=S(NEQ)                                        UGLD0046
      IF(NCL.EQ.2) GO TO 8                               UGLD0047
      DO 9 N=1,NM2                                       UGLD0048
      M=NM2-N+2                                          UGLD0049
9     S(M)=S(M-1)                                        UGLD0050
      IF(NCL.EQ.0) S(1)=0.0                              UGLD0051
      BUG=H(1)/H(2)                                      UGLD0052
      IF(NCL.EQ.1) S(1)=(1.0+BUG)*S(2)-BUG*S(3)          UGLD0053
8     IF(NCR.EQ.0) S(NIN)=0.0                            UGLD0054
      BUG=H(NM1)/H(NM2)                                  UGLD0055
      IF(NCR.EQ.1) S(NIN)=(1.0+BUG)*S(NM1)-BUG*S(NM2)    UGLD0056
      IF(NCR.EQ.2) S(NIN)=HOLD                           UGLD0057
      DO 10 N=1,NM1                                      UGLD0058
      AE(N)=(S(N+1)-S(N))/(SIX*H(N))                     UGLD0059
      M=N+NM1                                            UGLD0060
      AE(M)=HALF*S(N)                                    UGLD0061
      M=M+NM1                                            UGLD0062
      AE(M)=D(N)-H(N)*(TWO*S(N)+S(N+1))/SIX              UGLD0063
      M=M+NM1                                            UGLD0064
10    AE(M)=YIN(N)                                       UGLD0065
      RETURN                                             UGLD0066
      END                                                UGLD0067
```

```
      SUBROUTINE EVALDK(NIN,NOUT,XIN,XOUT,YOUT,A)
C     APRIL 1975 SPLINE PROGRAM SERIES   J.E.KERWIN
      DIMENSION XIN(1),XOUT(1),YOUT(1),A(1)
      NM1=NIN-1
      MOUT=IABS(NOUT)
      IF(NOUT.GT.0) GO TO 1
      DEL=(XIN(NIN)-XIN(1))/(MOUT-1)
      DO 2 N=1,MOUT
    2 XOUT(N)=XIN(1)+(N-1)*DEL
    1 J=1
      DO 3 N=1,MOUT
      IF(XOUT(N).GE.XIN(2)) GO TO 4
      J=1
      GO TO 5
    4 IF(XOUT(N).LT.XIN(NM1)) GO TO 6
      J=NM1
      GO TO 5
    6 IF(XOUT(N).GE.XIN(J+1)) GO TO 7
    9 IF (XOUT(N).LT.XIN(J)) GO TO 8
    5 H1=XOUT(N)-XIN(J)
      H2=H1**2
      H3=H1*H2
      J2=J+NM1
      J3=J2+NM1
      J4=J3+NM1
      YOUT(N)=A(J)*H3+A(J2)*H2+A(J3)*H1+A(J4)
      GO TO 3
    7 J=J+1
      GO TO 6
    8 J=J-1
      GO TO 9
    3 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SIMQ(A,B,N,KS)                                         SIMQ0001
      DIMENSION A(1),B(1)                                               SIMQ0002
      TOL=0.0                                                           SIMQ0003
      KS=0                                                              SIMQ0004
      JJ=-N                                                             SIMQ0005
      DO 65 J=1,N                                                       SIMQ0006
      JY=J+1                                                            SIMQ0007
      JJ=JJ+N+1                                                         SIMQ0008
      BIGA=0                                                            SIMQ0009
      IT=JJ-J                                                           SIMQ0010
      DO 30 I=J,N                                                       SIMQ0011
      IJ=IT+I                                                           SIMQ0012
      IF(ABS(BIGA)-ABS(A(IJ))) 20,30,30                                 SIMQ0013
   20 BIGA=A(IJ)                                                        SIMQ0014
      IMAX=I                                                            SIMQ0015
   30 CONTINUE                                                          SIMQ0016
      IF(ABS(BIGA)-TOL) 35,35, 40                                       SIMQ0017
   35 KS=1                                                              SIMQ0018
      RETURN                                                            SIMQ0019
   40 I1=J+N*(J-2)                                                      SIMQ0020
      IT=IMAX-J                                                         SIMQ0021
      DO 50 K=J,N                                                       SIMQ0022
      I1=I1+N                                                           SIMQ0023
      I2=I1+IT                                                          SIMQ0024
      SAVE=A(I1)                                                        SIMQ0025
      A(I1)=A(I2)                                                       SIMQ0026
      A(I2)=SAVE                                                        SIMQ0027
   50 A(I1)=A(I1)/BIGA                                                  SIMQ0028
      SAVE=B(IMAX)                                                      SIMQ0029
      B(IMAX)=B(J)                                                      SIMQ0030
      B(J)=SAVE/BIGA                                                    SIMQ0031
      IF(J-N) 55,70,55                                                  SIMQ0032
   55 IOS=N*(J-1)                                                       SIMQ0033
      DO 65 IX=JY,N                                                     SIMQ0034
      IXJ=IOS+IX                                                        SIMQ0035
      IT=J-IX                                                           SIMQ0036
```

```
      DO 60 JX=JY,N                                                     SIMQ0037
      IXJX=N*(JX-1)+IX                                                  SIMQ0038
      JJX=IXJX+IT                                                       SIMQ0039
   60 A(IXJX)=A(IXJX)-(A(IXJ)*A(JJX))                                   SIMQ0040
   65 B(IX)=B(IX)-(B(J)*A(IXJ))                                         SIMQ0041
   70 NY=N-1                                                            SIMQ0042
      IT=N*N                                                            SIMQ0043
      DO 80 J=1,NY                                                      SIMQ0044
      IA=IT-J                                                           SIMQ0045
      IB=N-J                                                            SIMQ0046
      IC=N                                                              SIMQ0047
      DO 80 K=1,J                                                       SIMQ0048
      B(IB)=B(IB)-A(IA)*B(IC)                                           SIMQ0049
      IA=IA-N                                                           SIMQ0050
   80 IC=IC-1                                                           SIMQ0051
      RETURN                                                            SIMQ0052
      END                                                               SIMQ0053
```

```
      SUBROUTINE EPLANT                                                 EPLT0001
      REAL LEN,NOFF,NCPO,NENL,NAC,KW,KW1                                EPLT0002
      COMMON/AA/ENDDAY,NOFF,NCPO,NENL                                   EPLT0003
      COMMON/BB/CN,DHV,ENCVOL,DAVG,AREADH,AREAHL,LEN                    EPLT0004
      COMMON/CC/SHPM,SHPE,VSUS,VE,RE,SFCM,SFCH,MTYPE,JOPT,MOPT,PC       EPLT0005
      COMMON/DD/ELKW,AVGKW,ELOAD,BLOAD,PALOAD                           EPLT0006
      IF(JOPT.EQ.2) GOTO 1                                              EPLT0007
      PALOAD=1.                                                         EPLT0008
      IF(MTYPE.EQ.2) PALOAD=15.                                         EPLT0009
      IF(MTYPE.EQ.3) PALOAD=71.                                         EPLT0010
      IF(MTYPE.EQ.4) PALOAD=71.                                         EPLT0011
    1 OALOAD=.0002695*CN                                                EPLT0012
      NAC=NOFF+NCPO+NENL                                                EPLT0013
      HLOAD=.917*NAC                                                    EPLT0014
      AVLOAD=15.+.376*NAC*CN/100000.                                    EPLT0015
      KW=ELOAD+BLOAD+PALOAD+OALOAD+HLOAD+AVLOAD                         EPLT0016
      AVGKW=KW-BLOAD                                                    EPLT0017
      KW1=1.25*(1.02*KW+ELOAD)                                          EPLT0018
      ELKW=100.                                                         EPLT0019
    2 IF(ELKW.GE.KW1) GOTO 3                                            EPLT0020
      IF(ELKW.LT.240.) GOTO 4                                           EPLT0021
      IF(ELKW.LT.900.) GOTO 5                                           EPLT0022
      ELKW=ELKW+500.                                                    EPLT0023
      GOTO 2                                                            EPLT0024
    4 ELKW=ELKW+50.                                                     EPLT0025
      GOTO 2                                                            EPLT0026
    5 ELKW=ELKW+250.                                                    EPLT0027
      GOTO 2                                                            EPLT0028
    3 RETURN                                                            EPLT0029
      END                                                               EPLT0030
```

```
      SUBROUTINE LIQ
      REAL NOFF,NCPO,NENL,NAC
      COMMON/AA/ENDDAY,NOFF,NCPO,NENL
      COMMON/CC/SHPM,SHPE,VSUS,VE,RE,SFCM,SFCH,MTYPE,JOPT,MOPT,PC
      COMMON/DD/ELKW,AVGKW,ELOAD,BLOAD,PALOAD
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL
      NAC=NOFF+NCPO+NENL
      WTPS=.186*NAC
      IF(JOPT.EQ.2) GOTO 1
      WTLO=.001*SHPM+5.
      IF(MTYPE.EQ.3) GO TO 2
      IF(MTYPE.EQ.4) GO TO 2
      IF(MTYPE.EQ.2) GO TO 6
      SFC=.5-.08*SHPE/SHPM
      SHPH=SHPM/2.
      IF(SHPM.GT.7000..AND.SHPE.LT.SHPH) SFC=.5-.16*SHPE/SHPM
      GO TO 3
    6 SFC=.54-.03*SHPE/SHPM
      SHPH=SHPM/2.
      IF(SHPM.GT.7000..AND.SHPE.LT.SHPH) SFC=.54-.16*SHPE/SHPM
      GO TO 3
    2 WTLO=.0001*SHPM+3.5
      IF(MTYPE.EQ.3) GO TO 7
      SFC=.92-.3*SHPE/SHPM
      IF(SHPM.GT.8000..AND.SHPM.LT.30000.) GO TO 9
      IF(SHPM.GT.30000.) SFC=.63-.2*SHPE/SHPM
      GO TO 3
    9 SFC=.77-.16*SHPE/SHPM
      GO TO 3
    7 SFC=.85-.28*SHPE/SHPM
      IF(SHPM.GT.8000..AND.SHPM.LT.30000.) GO TO 10
      IF(SHPM.GT.30000.) SFC=.49-.18*SHPE/SHPM
      GO TO 3
   10 SFC=.64-.16*SHPE/SHPM
      GO TO 3
    1 SFC=SFCM+(1.-SHPE/SHPM)*2.*(SFCH-SFCM)
```

```
3 FRMAIN=SFC*SHPE
  FRHOTL=.32*NAC
  FRGEN=.65*AVGKW
  FR=FRMAIN+FRHOTL+FRGEN
  WTFUEL=FR*RE/(1788.*VE)
  RETURN
  END
```

```
      SUBROUTINE MACHBX                                                 MCBX0001
      REAL KGTRY                                                        MCBX0002
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,      SFCMHP,SFCHHP,MTYPE,JOPT MCBX0003
     1,MOPT,PC                                                          MCBX0004
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP                     MCBX0005
      COMMON/JJ/H,SEP,XLB,DB,AG,XF,MBLOC1,MBLOC2                        MCBX0006
      COMMON/QQ/XMLOC1,YMLOC1,ZMLOC1,XMLOC2,YMLOC2,ZMLOC2               MCBX0007
C     MBLOC1=1>PROP IN HULL; MBLOC2=1,P.M.IN HULL;MBLOC2=2,P.M. IN BOX  MCBX0008
      IF(MTYPE.EQ.1) GO TO 2                                            MCBX0009
      IF(MTYPE.EQ.2) GO TO 31                                           MCBX0010
      IF(MTYPE.EQ.3) GO TO 41                                           MCBX0011
      IF(MTYPE.EQ.4) GO TO 5                                            MCBX0012
    2 CONTINUE                                                          MCBX0013
      MBLOC1=1                                                          MCBX0014
      XMLOC1=25.                                                        MCBX0015
      YMLOC1=DH                                                         MCBX0016
      ZMLOC1=DH                                                         MCBX0017
      MBLOC2=1                                                          MCBX0018
      XMLOC2=28.                                                        MCBX0019
      YMLOC2=DH                                                         MCBX0020
      ZMLOC2=DH                                                         MCBX0021
      IF(SHPM.GT.7000.) GO TO 21                                        MCBX0022
      GO TO 10                                                          MCBX0023
   21 MBLOC2=2                                                          MCBX0024
      XMLOC2=56.                                                        MCBX0025
      YMLOC2=3.*DH                                                      MCBX0026
      ZMLOC2=DB                                                         MCBX0027
      GO TO 10                                                          MCBX0028
   31 MBLOC2=2                                                          MCBX0029
      XMLOC2=28.                                                        MCBX0030
      YMLOC2=3.*DH                                                      MCBX0031
      ZMLOC2=DB                                                         MCBX0032
      MBLOC1=1                                                          MCBX0033
      XMLOC1=25.                                                        MCBX0034
      YMLOC1=DH                                                         MCBX0035
      ZMLOC1=DH                                                         MCBX0036
```

```
      IF(SHPM.GT.15000.) XMLOC1=50.                                     MCBX0037
      GO TO 10                                                          MCBX0038
   41 MBLOC2=2                                                          MCBX0039
      XMLOC2=20.+.00024*SHPM                                            MCBX0040
      YMLOC2=3.*DH                                                      MCBX0041
      ZMLOC2=9.                                                         MCBX0042
      MBLOC1=1                                                          MCBX0043
      XMLOC1=25.                                                        MCBX0044
      YMLOC1=DH                                                         MCBX0045
      ZMLOC1=DH                                                         MCBX0046
      IF(SHPM.GT.8000..AND.BS.GT.6.) GO TO 43                           MCBX0047
      GO TO 10                                                          MCBX0048
   43 MBLOC2=1                                                          MCBX0049
      XMLOC2=20.+.00048*SHPM                                            MCBX0050
      YMLOC2=DH                                                         MCBX0051
      ZMLOC2=DH                                                         MCBX0052
      GO TO 10                                                          MCBX0053
    5 MBLOC2=2                                                          MCBX0054
      XMLOC2=20.+.00024*SHPM                                            MCBX0055
      YMLOC2=3.*DH                                                      MCBX0056
      ZMLOC2=9.                                                         MCBX0057
      MBLOC1=1                                                          MCBX0058
      XMLOC1=25.                                                        MCBX0059
      YMLOC1=DH                                                         MCBX0060
      ZMLOC1=DH                                                         MCBX0061
      IF(SHPM.GT.15000.) XMLOC1=50.                                     MCBX0062
   10 CONTINUE                                                          MCBX0063
      RETURN                                                            MCBX0064
      END                                                               MCBX0065
```

```
      SUBROUTINE VOLUME
      REAL LEN,NOFF,NCPO,NENL,KGTRY,NAC
      COMMON/AA/D,NOFF,NCPO,NENL
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,       SFCMHP,SFCHHP,MTYPE,JOPT
     1,MOPT,PC
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP
      COMMON/JJ/H,SEP,XLB,DB,AG,XP,MBLOC1,MBLOC2
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL
      COMMON/PP/VMB,TANKVL,AVAA,DHAA,ODA,XMFDA,CSDA,OSRDA,OHDA,CPODA,
     1CPOHDA,CBDA,CHDA,CODA,CSTDA,OSDA,WDA,RLDA,CLDA,UTDA,SGDA,ACDA,XICD
     2A,AMDA,PHDA,WSDA,VMXA
      COMMON/QQ/XMLOC1,YMLOC1,ZMLOC1,XMLOC2,YMLOC2,ZMLOC2
      KNDEX=0
      VMX=0.
      NAC=NOFF+NCPO+NENL
      THV=2.*(.785398*DH*DH*(LEN-8.*DH)+3.665191*DH*DH*DH)
      VFUEL=WTFUEL*43.
      VLO=WTLO*39.
      VFW=.186*NAC*36.
      VACFUL=WACFUL*44.1
      TANKVL=(VFUEL+VLO+VFW+VACFUL)*1.2
      IF(MBLOC2.EQ.1) GO TO 1
C     MACHINERY IN BOX
      VMX=XMLOC2*YMLOC2*ZMLOC2
      VMH=1.570796*XMLOC1*DH*DH
      GO TO 2
    1 VMH=1.570796*(XMLOC1+XMLOC2)*DH*DH
      GO TO 2
    2 DHV=.007*LEN*LEN*LEN
    3 STV=2.*((XLS*BS*CWP)*(H-DH+AG)+XLS*(.5*BS*(DH-.5*DH*SQRT(1.-BS*BS/
     1(DH*DH)))-.25*DH*DH*ARSIN(BS/DH)))
      FILV=XLS*BS*BS
      BOXV=XLB*BBOX*13.
      BAAA=BOXV/13.
    4 TEV=THV+STV+FILV+BOXV+DHV
```

```
      CN=TEV-DHV
      SGDA=.0042*CN+450.
      RHV=TANKVL+VMH+SGDA*9.
      IF(THV.GT.RHV) GO TO 5
C     CAN ADD LIQUIDS TO STRUT TO ATTAIN BALANCE
      VHULSS=THV+.3*STV
      IF(VHULSS.GT.RHV) GO TO 5
      GO TO 1000
C     HULLS CHECK OUT - NOW CHECK DECKHOUSE
    5 RDHA=1.1*(2.37*LEN+24.+.00225*CN+AREADH)
      DHAA=DHV/9.
C     ASSUME ONE USEABLE PLATFORM IN STRUTS OVER 75 PERCENT OF LENGTH
      SAAA=XLS*BS*CWP*1.5
      IF(RDHA.GT.DHAA) GO TO 1000
      AVAA=BAAA+SAAA
      TAAA=DHAA+BAAA+SAAA
      ODA=2.12*LEN-232.
      IF(ODA.LT.0.) ODA=0.
      XMFDA=11.9*NAC+500.
      CSDA=4.23*NAC
      OSRDA=73.*NOFF
      OHDA=12.*NOFF
      CPODA=40.*NCPO
      CPOHDA=8.*NCPO
      CBDA=22.*NENL
      CHDA=5.*NENL
      CODA=2.37*LEN-76.
      CSTDA=300.+.021*D*NAC
      OSDA=.00539*CN
      WDA=.00314*CN-157.
      IF(WDA.LT.0.) WDA=0.
      RLDA=145.
      CLDA=40.
      ACDA=.00088*CN
      XICDA=.88*LEN+4.
      AMDA=.0097*CN
```

```
      PHDA=100.+.00225*CN
      WSDA=5.*LEN-475.
      VMXA=VMX/9.
      UTDA=0.
      IF(JOPT.EQ.2) GO TO 6
      UTDA=700.
      IF(MBLOC2.EQ.1) GO TO 6
      UTDA=200.
    6 TRAA=1.1*(AREADH+AREAHL+ODA+XMFDA+CSDA+OSRDA+OHDA+CPODA+CPOHDA+
     1CBDA+CHDA+CODA+CSTDA+OSDA+WDA+RLDA+CLDA+UTDA+      ACDA+XICDA+AMDA+
     2PHDA+WSDA+VMXA )
      IF(TRAA.GT.TAAA) GO TO 10
C     REDUCE DECKHOUSE VOLUME
      DHSV=.00223*LEN*LEN*LEN
      DHSAA=DHSV/9.
      DHAMIN=AMAX1(DHSAA,RDHA)
      TAAA=DHAMIN+BAAA+SAAA
      IF(TRAA.GT.TAAA) GO TO 11
      DHV=9.*DHAMIN
      DHAA=DHAMIN
      GO TO 13
   12 DHV=DHSV
      DHAA=DHV/9.
   13 ENCVOL=CN+DHV
      VMB=VMX+VMH
      RETURN
   11 DHAR=TRAA-AVAA
      DHSV=DHAR*9.
      GO TO 12
C     ADD ANOTHER DECK IN BOX
   10 DB=22.
      BOXV=BOXV*1.6923
      BAAA=XLB*BBOX*2.
      IF(KNDEX.GT.1) GO TO 1000
      KNDEX=KNDEX+1
      GO TO 4
```

```
 1000 LEN=-10.0
      RETURN
      END
```

```
      SUBROUTINE WEIGHT
      REAL LEN,NOFF,NCPO,NENL,NAC
      COMMON/AA/D,NOFF,NCPO,NENL
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/CC/SHPM,SHPE,VSUS,VEND,RGEND,      SFCMHP,SFCHHP,MTYPE,JOPT
     1,MOPT,PC
      COMMON/DD/ELKW,AVGKW,ELOAD,BLOAD,PALOAD
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP
      COMMON/JJ/H,SEP,XLB,DB,AG,XF,MBLOC1,MBLOC2
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAR
      IF(DB.LE.13.) GO TO 1
C     TWO DECK BOXES--STEEL FIRST,TEST MOPT,THEN ALUMINUM
      WT1=.82285*DPTRY-54.40049*DPTRY*DPTRY/CN
      IF(MOPT.EQ.2) WT1=.542222*DPTRY-34.84444*DPTRY*DPTRY/CN
      GO TO 2
C     ONE DECK BOXES
    1 WT1=.83335*DPTRY-41.8151*DPTRY*DPTRY/CN
      IF(MOPT.EQ.2) WT1=.577857*DPTRY-32.000039*DPTRY*DPTRY/CN
C     THE WEIGHT EQUATIONS ARE BASED ON WT1 + 15 PERCENT -- REDUCE 15 %
    2 WT1=.85*WT1
      WT111=.000353*DHV
      WTG1=WT1+WT111
      IF(JOPT.EQ.2) GO TO 3
      WTG2=.03754*SHPM**.925
      IF(MTYPE.EQ.2) WTG2=.109828*SHPM**.86
      IF(MTYPE.EQ.3) WTG2=.339053*SHPM**.634
      IF(MTYPE.EQ.4) WTG2=.4777*SHPM**.692
      IF(MTYPE.EQ.3.AND.MBLOC2.EQ.2) WTG2=WTG2+.001*SHPM-2.033
      IF(MTYPE.EQ.1.AND.MBLOC2.EQ.2) WTG2=WTG2+.001*SHPM-2.033
    3 CONTINUE
C     GOODWIN DATA AND ASSUMPTIONS USED FOR GROUP THREE WEIGHTS
      WT300=.054*ELKW
      IF(ELKW.GE.500.) WT300=41.54+.01068*ELKW
      IF(ELKW.GE.800.) WT300=5.38+.06748*ELKW
      WT301=.01335*ELKW
```

```
      WT3R=.0001534*ENCVOL                                              WGHT0037
      WTG3=WT300+WT301+WT3R                                             WGHT0038
      VOL=ENCVOL/100000.                                                WGHT0039
C     DD07 GROUP 5 CURVE REDUCED 20 PERCENT FITS SWATHS --USED HERE     WGHT0040
      WTG5=-2.3072*VOL*VOL+65.456*VOL                                   WGHT0041
C     WTG6 CURVE FITTED TO SWATH DATA AVAILABLE AS FUNCTION OF ENCVOL   WGHT0042
      WTG6=.05318*ENCVOL**.6266                                         WGHT0043
      WLSHIP=(WTG1+WTG2+WTG3+WTG4+WTG5+WTG6+WTG7)*DBMAR                 WGHT0044
C     CALCULATE LOADS                                                   WGHT0045
      NAC=NOFF+NCPO+NENL                                                WGHT0046
      WTCREW=.0737*NAC                                                  WGHT0047
      WTPE=.105*NOFF+.0737*NCPO+.029*NENL                               WGHT0048
      WTPS=(.0222+.00202*D)*NAC+.00135*D*NAC+.186*NAC                   WGHT0049
      WFULLD=WLSHIP+WTCREW+WTPE+WTPS+WTLO+WTFUEL+WCARGO+WTAMMO+WTAC+    WGHT0050
     1WACFUL                                                            WGHT0051
      RETURN                                                            WGHT0052
      END                                                               WGHT0053
```

```
      SUBROUTINE VCG(CFULD)
      REAL LEN
      COMMON/AA/D,OFF,CPD,ENL
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN
      COMMON/CC/SHPM,SHPE,VSUS,VE,RE,SFCM,SFCH,MTYPE,JOPT,MOPT,PC
      COMMON/EE/GR4WT(20),GR4CG(20),GR7WT(20),GR7CG(20),AMOWT(20),
     1AMOCG(20),ACWT(20),ACCG(20),CARGOW(20),CARGOC(20)
      COMMON/FF/TITLE(5,40),HEAD(20),NOARM,NOELT
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP
      COMMON/HH/CGFUEL,CGLO,CGCREW,CGPE,CGPS,CCARGO,CGAMMO,CGAC,CACFUL
      COMMON/JJ/H,SEP,XLB,DB,AG,XF,MBLOC1,MBLOC2
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL
      COMMON/OO/CGG1,CGG2,CGG3,CGG4,CGG5,CGG6,CGG7,CLSHIP,CFULLD
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAE
      DECKS=1.
      IF(DB.GT.13.) DECKS=2.
      DT=H+AG+DB
      CGG1=.605*DT
      IF(DECKS.EQ.1..AND.MOPT.EQ.1) CGG1=.58*DT
      IF(DECKS.EQ.1..AND.MOPT.EQ.2) CGG1=.57*DT
      CGG2=.15*DT
      IF(MTYPE.EQ.1.AND.SHPM.GT.7000.) CGG2=.65*DT
      IF(MTYPE.EQ.2) CGG2=.39*DT
      IF(MTYPE.EQ.3.AND.MBLOC2.EQ.2) CGG2=.40*DT
      IF(MTYPE.EQ.3.AND.MBLOC2.EQ.1) CGG2=.22*DT
      IF(MTYPE.EQ.4) CGG2=.43*DT
    7 CGG3=.869*DT
      IF(DECKS.EQ.2.) CGG3=.782*DT
      CGG5=.67*DT
      IF(DECKS.EQ.2.) CGG5=.78*DT
      CGG6=.88*DT
      IF(DECKS.EQ.2.) CGG6=.77*DT
      G4MOM=0.
      DO 10 I=1,NOELT
   10 G4MOM=G4MOM+GR4WT(I)*GR4CG(I)
      CGG4=0.
```

```
      IF(G4MOM.GT.1.) CGG4=G4MOM*DT/WTG4
      ACMOM=0.
      G7MOM=0.
      AMOMOM=0.
      CGOMOM=0.
      DO 20 I=1,NOARM
      ACMOM=ACMOM+ACWT(I)*ACCG(I)
      G7MOM=G7MOM+GR7WI(I)*GR7CG(I)
      AMOMOM=AMOMOM+AMOWT(I)*AMOCG(I)
   20 CGOMOM=CGOMOM+CARGOW(I)*CARGOC(I)
      CGG7=0.
      IF(G7MOM.GT.1.) CGG7=G7MOM*DT/WTG7
      CCARGO=0.
      IF(CGOMOM.GT.1.) CCARGO=CGOMOM*DT/WCARGO
      CGAC=0.
      IF(ACMOM.GT.1.) CGAC=ACMOM*DT/WTAC
      CGAMMO=0.
      IF(AMOMOM.GT.1.) CGAMMO=AMOMOM*DT/WTAMMO
      CACFL=CACFUL*DT
      CLSHIP=(CGG1*WTG1+CGG2*WTG2+CGG3*WTG3+CGG4*WTG4+CGG5*WTG5+CGG6*
     1WTG6+CGG7*WTG7)*DBMAR/WLSHIP
      CGFUEL=.5*DH
      CGLO=.83*DT
      CGCREW=.89*DT
      CGPE=CGCREW
      CGPW=.5*DH
      CGGS=.83*DT
      CGPV=.85*DT
      CGPS=((.0222+.00202*D)*CGPV+.00135*D*CGGS+.186*CGPW)/(.2082+.00337
     1*D)
      XLDMOM=(CGFUEL*WTFUEL+CGLO*WTLO+CGCREW*WTCREW+CGPE*WTPE+CGPS*WTPS+
     1CCARGO*WCARGO+CGAMMO*WTAMMO+CGAC*WTAC+CACFL *WACFUL)
      CFULLD=(CLSHIP*WLSHIP+XLDMOM)/WFULLD
      CFULD=CFULLD
      RETURN
      END
```

```
      SUBROUTINE COST(LEN)                                              COST0001
      REAL MCST                                                         COST0002
      REAL LEN,LABCST,MATCST,LOA                                        COST0003
      COMMON/CC/SHPM,SHPE,VSUS,VE,RE,SFCM,SFCH,MTYPE,JOPT,MOPT,PC       COST0004
      COMMON/MM/CSTG1,CSTG2,CSTG3,CSTG4,CSTG5,CSTG6,CSTG7,DCST,CCST,MCST COST0005
      COMMON/NN/ DOLHR,G1IND,G2IND,G3IND,G5IND,G6IND,TOTCST             COST0006
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAR  COST0007
      W1=WTG1*DBMAR                                                     COST0008
      W2=WTG2*DBMAR                                                     COST0009
      W3=WTG3*DBMAR                                                     COST0010
      W4=WTG4*DBMAR                                                     COST0011
      W5=WTG5*DBMAR                                                     COST0012
      W6=WTG6*DBMAR                                                     COST0013
      W7=WTG7*DBMAR                                                     COST0014
      G1MH=10.**(ALOG10(W1)*.75217+2.97276)                             COST0015
      G2MH=10.**(ALOG10(W2)*1.0273+2.3437)                              COST0016
      G3MH=10.**(ALOG10(W3)*1.07776+2.62981)                            COST0017
      G4MH=10.**(ALOG10(W4)*1.07776+2.62981)                            COST0018
      G5MH=10.**(ALOG10(W5)*.763428+3.2366)                             COST0019
      G6MH=10.**(ALOG10(W6)*.9742+2.74181)                              COST0020
      G7MH=10.**(ALOG10(W7)*.75217+2.97276)                             COST0021
      G1MC=10.**(ALOG10(W1)*.954243+2.790484)                           COST0022
      IF(MOPT.EQ.2) G1MC=1.3*G1MC                                       COST0023
      G2MC=CSTG2                                                        COST0024
      IF(JOPT.EQ.2) GOTO 1                                              COST0025
      G2MC=10.**(ALOG10(W2)*1.018885+3.634328)                          COST0026
      IF(MTYPE.EQ.2) G2MC=G2MC+2000000.                                 COST0027
      IF(MTYPE.EQ.3) G2MC=451640.*W2**.53                               COST0028
      IF(MTYPE.EQ.4) G2MC=451640.*W2**.53+2000000.                      COST0029
    1 G3MC=10.**(ALOG10(W3)*1.072551+3.667812)                          COST0030
      G4MC=CSTG4                                                        COST0031
      G5MC=10.**(ALOG10(W5)*.870906+3.974192)                           COST0032
      G6MC=10.**(ALOG10(W6)*1.068265+3.603833)                          COST0033
      G7MC=CSTG7                                                        COST0034
      G1LC=G1MH*DOLHR*1.98                                              COST0035
      G2LC=G2MH*DOLHR*1.98                                              COST0036
```

```
      G3LC=G3MH*DOLHR*1.98
      G4LC=G4MH*DOLHR*1.98
      G5LC=G5MH*DOLHR*1.98
      G6LC=G6MH*DOLHR*1.98
      G7LC=G7MH*DOLHR*1.98
      G1MC=G1MC*G1IND*1.1
      IF(JOPT.EQ.2) GOTO 2
      G2MC=G2MC*G2IND
    2 G3MC=G3MC*G3IND*1.1
      G5MC=G5MC*G5IND*1.1
      G6MC=G6MC*G6IND*1.1
      G2MC=G2MC*1.1
      G4MC=G4MC*1.1
      G7MC=G7MC*1.1
      LABCST=G1LC+G2LC+G3LC+G4LC+G5LC+G6LC+G7LC
      MATCST=G1MC+G2MC+G3MC+G4MC+G5MC+G6MC+G7MC
      LOA=1.*LEN
      FACTOR=(.114*LOA-1.6)/100.
      DLC=FACTOR*LABCST
      FACTOR=(-.01*LOA+7.5)/100.
      DMC=FACTOR*MATCST
      FACTOR=(.014*LOA+7.)/100.
      CLC=FACTOR*LABCST
      FACTOR=(-.015*LOA+6.5)/100.
      CMC=FACTOR*MATCST
      TOTCST=LABCST+MATCST+DLC+DMC+CLC+CMC
      ORICST=.02*TOTCST
      SPARES=(.09*G2MC+.08*G3MC+.25*G4MC+.1*G5MC)/1.1
      RETRO=.04*TOTCST
      ADMIN=.035*TOTCST
      CSTG1=G1LC+G1MC
      CSTG2=G2LC+G2MC
      CSTG3=G3LC+G3MC
      CSTG4=G4LC+G4MC
      CSTG5=G5LC+G5MC
      CSTG6=G6LC+G6MC
```

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      CSTG7=G7LC+G7MC                                                   COST0073
      DCST=DLC+DMC                                                      COST0074
      CCST=CLC+CMC                                                      COST0075
      MCST=ORICST+SPARES+RETRO+ADMIN                                    COST0076
      TOTCST=TOICST+MCST                                                COST0077
      RETURN                                                            COST0078
      END                                                               COST0079
```

```
      SUBROUTINE OUTPUT(EXCKG,I1)                                       OUTP0001
      REAL LEN,NOFF,NCPO,NENL,KGTRY,MCST                                OUTP0002
      COMMON/AA/D,NOFF,NCPO,NENL                                        OUTP0003
      COMMON/BB/CN,DHV,ENCVOL,DT,AREADH,AREAHL,LEN                      OUTP0004
      COMMON/CC/SHPM,SHPE,VSUS,VE,RE,     SFCM,SFCH,MTYPE,JOPT,MOPT,PC  OUTP0005
      COMMON/DD/ELKW,AVKW,ELOAD,BLOAD,PALOAD                            OUTP0006
      COMMON/EE/GR4WT(20),GR4CG(20),GR7WT(20),GR7CG(20),AMOWT(20),      OUTP0007
     1AMOCG(20),ACWT(20),ACCG(20),CARGOW(20),CARGOC(20)                 OUTP0008
      COMMON/FF/TITLE(5,40),HEAD(20),NOARM,NOELT                        OUTP0009
      COMMON/GG/FRSC,KGTRY,DPTRY,DH,BBOX,BS,XLS,CWP                     OUTP0010
      COMMON/HH/CGFUEL,CGLO,CGCREW,CGPE,CGPS,CCARGO,CGAMMO,CGAC,CACFUL  OUTP0011
      COMMON/II/JNDEX,LNDEX                                             OUTP0012
      COMMON/JJ/H,SEP,XLB,DB,AG,XF,MBLOC1,MBLOC2                        OUTP0013
      COMMON/KK/ELLD(20),DHAR(20),HLAR(20),ELD(20),DHA(20),HLA(20),     OUTP0014
     1GR7CST(20),GR4CST(20)                                             OUTP0015
      COMMON/LL/WTFUEL,WTLO,WTCREW,WTPE,WTPS,WCARGO,WTAMMO,WTAC,WACFUL  OUTP0016
      COMMON/MM/CSTG1,CSTG2,CSTG3,CSTG4,CSTG5,CSTG6,CSTG7,DCST,CCST,MCST OUTP0017
      COMMON/NN/DOLHR,G1IND,G2IND,G3IND,G5IND,G6IND,TOTCST              OUTP0018
      COMMON/OO/CGG1,CGG2,CGG3,CGG4,CGG5,CGG6,CGG7,CLSHIP,CFULLD        OUTP0019
      COMMON/PP/VMB,TANKVL,AVAA,DHAA,ODA,XMFDA,CSDA,OSRDA,OHDA,CPODA,   OUTP0020
     1CPOHDA,CBDA,CHDA,CODA,CSTDA,OSDA,WDA,RLDA,CLDA,UIDA,SGDA,ACDA,XICD OUTP0021
     2A,AMDA,PHDA,WSDA,VMXA                                             OUTP0022
      COMMON/QQ/XMLOC1,YMLOC1,ZMLOC1,XMLOC2,YMLOC2,ZMLOC2               OUTP0023
      COMMON/RR/IREAD,IWRITE                                            OUTP0024
      COMMON/WW/WTG1,WTG2,WTG3,WTG4,WTG5,WTG6,WTG7,WLSHIP,WFULLD,DBMAR  OUTP0025
      WRITE(IWRITE,100) HEAD                                            OUTP0026
  100 FORMAT('1',20A4/)                                                 OUTP0027
      WRITE(IWRITE,101)                                                 OUTP0028
  101 FORMAT(T30,'*****INPUT DATA*****'//' ARMAMENT,AIRCRAFT AND CARGO  OUTP0029
     1INPUTS'//,T9,'ITEM',T26,'CARGO   CARGO  GROUP 7 GROUP 7  AMMO',T66 OUTP0030
     2,'AMMO  AIRCRAFTAIRCRAFT  ELECT  AREA IN AREA IN GROUP 7'/,T25,   OUTP0031
     3'WEIGHT    VCG   WEIGHT    VCG   WEIGHT   VCG    WEIGHT   VCG',T90 OUTP0032
     4,'LOAD  DECKHSE   HULL    COST'/)                                 OUTP0033
      WRITE(IWRITE,102)((TITLE(J,I),J=1,5),CARGOW(I),CARGOC(I),GR7WT(I), OUTP0034
     1GR7CG(I),AMOWT(I),AMOCG(I),ACWT(I),ACCG(I),ELLD(I),DHAR(I),HLAR(I) OUTP0035
     2,GR7CST(I),I=1,NOARM)                                             OUTP0036
```

```
102 FORMAT(' ',5A4,F8.1,F8.3,F8.1,F8.3,F8.1,F8.3,F8.1,F8.3,F8.3,F8.0,    OUTP0037
   1F8.0,F8.0)                                                            OUTP0038
    WRITE(IWRITE,103)                                                     OUTP0039
103 FORMAT(/' ELECTRONICS INPUT'//T9,'ITEM',T24,'GROUP 4 GROUP 4',T41,   OUTP0040
   1'ELECT  AREA IN AREA IN GROUP 4'/,T24,'WEIGHT   VCG      LOAD',T48,  OUTP0041
   2'DECKHSE  HULL    COST'/)                                             OUTP0042
    WRITE(IWRITE,104) ((TITLE(J,I+20),J=1,5),GR4WT(I),GR4CG(I),ELD(I),   OUTP0043
   1DHA(I),HLA(I),GR4CST(I),I=1,NOELT)                                    OUTP0044
104 FORMAT(' ',5A4,F8.1,2F8.3,3F8.0)                                      OUTP0045
    WRITE(IWRITE,105)                                                     OUTP0046
105 FORMAT(/' MANNING INPUT'/)                                            OUTP0047
    WRITE(IWRITE,106) NOFF,NCPO,NENL                                      OUTP0048
106 FORMAT('  NO. OF OFFICERS = ',F5.0,5X,'NO. OF CPOS = ',F5.0,5X,      OUTP0049
   1'NO. OF ENLISTED MEN = ',F5.0,/)                                      OUTP0050
    WRITE(IWRITE,121)                                                     OUTP0051
121 FORMAT(' COST INDICES INPUT'/)                                        OUTP0052
    WRITE(IWRITE,119) DOLHR,G1IND,G2IND,G3IND,G5IND,G6IND                 OUTP0053
119 FORMAT('  LABOR RATE = ',F5.2,' DOLLARS/HR'/'  GROUP 1 INDEX = ',    OUTP0054
   1F5.2/'  GROUP 2 INDEX = ',F5.2/'  GROUP 3 INDEX = ',F5.2/'  GROUP     OUTP0055
   25 INDEX = ',F5.2/'  GROUP 6 INDEX = ',F5.2/)                         OUTP0056
    WRITE(IWRITE,120)                                                     OUTP0057
120 FORMAT('       INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MAT   OUTP0058
   1ERIAL COSTS'/)                                                        OUTP0059
    WRITE(IWRITE,107)                                                     OUTP0060
107 FORMAT(' MILITARY MISSION CONSUMABLES INPUT'/)                        OUTP0061
    WRITE(IWRITE,108) D,WACFUL,CACFUL                                     OUTP0062
108 FORMAT('  NO. ENDURANCE DAYS = ',F5.0,'  WEIGHT AIRCRAFT FUEL = ',   OUTP0063
   1F7.1,'  VCG AIRCRAFT FUEL = ',F8.3)                                   OUTP0064
    DBMAR=DBMAR-1.                                                        OUTP0065
    WRITE(IWRITE,109)                                                     OUTP0066
109 FORMAT(/,' VEHICLE PERFORMANCE INPUT')                                OUTP0067
    IF(JOPT.EQ.2) GOTO 2                                                  OUTP0068
    WRITE(IWRITE,110) VSUS,VE,RE,PC                                       OUTP0069
110 FORMAT(/'  MAX SUSTAINED SHP COMPUTED'/,' SUSTAINED SPEED = ',F8.2   OUTP0070
   1,' KTS'/,' ENDURANCE SPEED = ',F8.2,' KTS'/,' ENDURANCE RANGE = ',   OUTP0071
   2F8.0,' MILES'/,' PROP COEFF = ',F5.3/)                                OUTP0072
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```
      GOTO 3
    2 WRITE(IWRITE,111) SHPM,WTG2,SFCM,SFCH,VE,RE,PALOAD,PC,CSTG2,WTLO,
     1MBLOC1,XMLOC1,MBLOC2,XMLOC2,YMLOC2,ZMLOC2
  111 FORMAT('  MAX SUSTAINED SPEED COMPUTED'/,' MAX SUSTAINED SHP = ',
     1F8.0,/,' GROUP 2 WEIGHT = ',F8.1,' TONS'/,' SFC MAX POWER = ',F5.3
     2,' LBS/SHP-HR'/,' SFC HALF POWER = ',F5.3,' LBS/SHP-HR'/,' ENDURAN
     3CE SPEED = ',F8.2,' KTS'/,' ENDURANCE RANGE = ',F8.0,' MILES'/,' P
     4ROP AUX ELECT LOAD = ',F8.3,' KW'/,' PROP COEFFICIENT = ',F5.3,/,
     5' GROUP 2 COST = ',F9.0,' DOLLARS'/,' WEIGHT OF LUBE OIL = ',F8.1,
     6' TONS'/,' PROPULSOR LOCATION = ',I1,' 1=HULL '/,' PROPULSOR LENGT
     7H = ',F5.2,' FEET '/,' PRIME MOVER LOC = ',I1,' 2=BOX '/,' MACHY S
     8PACE DIMS (L X W X H) = ',F5.2,' X ',F5.2,' X ',F5.2,' FEET'/)
    3 WRITE(IWRITE,112) MTYPE,FRSC,DBMAR,LEN,MOPT
  112 FORMAT('  OPTIONS'//,' MTYPE = ',I2,/,' FREE SURFACE CORRECTION =
     1',F5.2,' FT',/,' DESIGN AND BUILDERS MARGIN = ',F5.3,/,' LENGTH =
     2',F5.1,' FT',/,' MATERIAL = ',I2,' 1=STL,2=AL ',/)
      IF(I1.EQ.1) RETURN
      WRITE(IWRITE,113)
  113 FORMAT(//,T33,'*****OUTPUT*****'//,'  LENGTH  BEAM  DRAFT  DIAM
     1LSTRUT  BSTRUT  CWP   LBOX  BBOX  DBOX  DISPLACEMENT  SHPMAX VSUS
     2 SHPEND'/)
      WRITE(IWRITE,114) LEN,BBOX,H,DH,XLS,BS,CWP,XLB,BBOX,DB,DPTRY,SHPM,
     1VSUS,SHPE
  114 FORMAT(' ',F6.1,F8.2,F7.2,F6.2,F8.2,F7.2,F6.3,F7.2,2F6.2,F11.2,F10
     1.2,F6.2,F9.2)
      VOL=ENCVOL-DHV
      WRITE(IWRITE,115) ELKW
  115 FORMAT(/,' ELECTRIC PLANT CAPACITY/GEN = ',F8.0,' KW'/)
      FFF=1.+DBMAR
      R1=WTG1/WFULLD*FFF
      R2=WTG1/WLSHIP*FFF
      R3=WTG2/WFULLD*FFF
      R4=WTG2/WLSHIP*FFF
      R5=WTG3/WFULLD*FFF
      R6=WTG3/WLSHIP*FFF
      R7=WTG4/WFULLD*FFF
```

```
      R8=WTG4/WLSHIP*FFF
      R9=WTG5/WFULLD*FFF
      R10=WTG5/WLSHIP*FFF
      R11=WTG6/WFULLD*FFF
      R12=WTG6/WLSHIP*FFF
      R13=WTG7/WFULLD*FFF
      R14=WTG7/WLSHIP*FFF
      R15=WLSHIP/WFULLD
      R16=1.
      WRITE(IWRITE,116) WTG1,CGG1,R1,R2,CSTG1,WTG2,CGG2,R3,R4,CSTG2,WTG3
     1,CGG3,R5,R6,CSTG3,WTG4,CGG4,R7,R8,CSTG4,WTG5,CGG5,R9,R10,CSTG5,WTG
     26,CGG6,R11,R12,CSTG6,WTG7,CGG7,R13,R14,CSTG7,WLSHIP,CLSHIP,R15,R16
     3,TOTCST
  116 FORMAT(/' ',8X,'WEIGHTS       VCG       WT/WFULLD   WT/WLSHIP      CO
     1ST'//' WTG1',F10.1,3F12.3,F12.0/' WTG2',F10.1,3F12.3,F12.0/' WTG3'
     2,F10.1,3F12.3,F12.0/' WTG4',F10.1,3F12.3,F12.0/' WTG5',F10.1,3F12.
     33,F12.0/' WTG6',F10.1,3F12.3,F12.0/' WTG7',F10.1,3F12.3,F12.0//,
     4' WLSHIP',F8.1,3F12.3,F12.0,' = TOTAL COST'/)
      R1=WTFUEL/WFULLD
      R2=WTLO/WFULLD
      R3=WTCREW/WFULLD
      R4=WTPE/WFULLD
      R5=WTPS/WFULLD
      R6=WCARGO/WFULLD
      R7=WTAMMO/WFULLD
      R8=WTAC/WFULLD
      R9=WACFUL/WFULLD
      CACFL=CACFUL*DT
      WRITE(IWRITE,117) WTFUEL,CGFUEL,R1,WTLO,CGLO,R2,WTCREW,CGCREW,R3,
     1WTPE,CGPE,R4,WTPS,CGPS,R5,WCARGO,CCARGO,R6,WTAMMO,CGAMMO,R7,WTAC,
     2CGAC,R8,WACFUL,CACFL ,R9,WFULLD,CFULLD
  117 FORMAT(' FUEL',F10.1,2F12.3/' LUB OIL',F7.1,2F12.3/' CREW',F10.1,
     12F12.3/' PER EFF',F7.1,2F12.3/' PER STR',F7.1,2F12.3/' CARGO',F9.1
     2,2F12.3/' AMMO',F10.1,2F12.3/' AIR CFT',F7.1,2F12.3/' A/C FUEL',
     3F6.1,2F12.3//' WFULLD',F8.1,F12.3//)
      WRITE(IWRITE,122) EXCKG
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122 FORMAT(' A MARGIN ON KG OF ',F6.3,' FT EXISTS ABOVE THE FULL LOAD      OUTP0145
   1KG VALUE GIVEN '//)                                                    OUTP0146
    WRITE(IWRITE,118) DCST,CCST,MCST                                       OUTP0147
118 FORMAT(' NOTE   D&B MARGIN INCLUDED IN WLSHIP AND COST ESTIMATES B     OUTP0148
   1UT NOT IN INDIVIDUAL WEIGHT GROUPS'/'        OVERHEAD AND PROFIT A     OUTP0149
   2RE INCLUDED IN INDIVIDUAL WEIGHT GROUP COSTS'/'         TOTAL COST     OUTP0150
   3INCLUDES A DESIGN COST OF',F12.0,' DOLLARS'/' ',19X,'A CONST SERVI     OUTP0151
   4CES COST OF',F12.0,' DOLLARS'/' ',19X,'AND A MISC. ITEM COST OF',      OUTP0152
   5F12.0,' DOLLARS'/'          MISC.ITEM COST INCLUDES ORI OUTFIT, SPAR   OUTP0153
   6ES, RETROFIT COSTS, AND ADMINISTRATIVE COSTS(RIO)'/)                   OUTP0154
    WRITE(IWRITE,123) VOL,DHV                                              OUTP0155
123 FORMAT(/,' VOLUME HULLS,STRUTS&BOX = ',F10.0,' CU FT'/,' VOLUME OF     OUTP0156
   1 DECKHOUSE       = ',F10.0,' CU FT'/)                                  OUTP0157
    AAVOM=VOL-VMB-TANKVL+DHV                                               OUTP0158
    R1=VMB/ENCVOL                                                          OUTP0159
    R2=TANKVL/ENCVOL                                                       OUTP0160
    R3=AAVOM/ENCVOL                                                        OUTP0161
    WRITE(IWRITE,124) VMB,R1,TANKVL,R2,AAVOM,R3                            OUTP0162
124 FORMAT(/,T26,'VOLUME(CU FT)      VOL/ENCVOL'//' MACHINERY ROOM',T28    OUTP0163
   1,F10.0,F15.3/' TANKAGE',T28,F10.0,F15.3/' ARRANGEMENTS',T28,F10.0,     OUTP0164
   2F15.3/)                                                                OUTP0165
    AR=AVAA+DHAA                                                           OUTP0166
    WRITE(IWRITE,125) AR,AVAA,DHAA                                         OUTP0167
125 FORMAT(/' TOTAL ARRANGEMENTS AREA = ',F8.0/' HULL ARRANGEMENTS ARE     OUTP0168
   1A = ',F9.0/' DKHSE ARRANGEMENT AREA = ',F8.0/)                         OUTP0169
    WRITE(IWRITE,126)                                                      OUTP0170
126 FORMAT(' ',T30,'AREA(SQ FT)  AREA/TOT AREA'/)                          OUTP0171
    R4=ODA/AR                                                              OUTP0172
    R5=XMFDA/AR                                                            OUTP0173
    R6=CSDA/AR                                                             OUTP0174
    R7=OSRDA/AR                                                            OUTP0175
    R8=OHDA/AR                                                             OUTP0176
    WRITE(IWRITE,127) ODA,R4,XMFDA,R5,CSDA,R6,OSRDA,R7,OHDA,R8             OUTP0177
127 FORMAT(' OFFICE SPACE',T30,F10.0,F13.3,/' MESSING FACILITIES',T30,     OUTP0178
   1F10.0,F13.3/' CREW SPECIAL',T30,F10.0,F13.3/' OFFICER S.R.',T30,       OUTP0179
   2F10.0,F13.3/' OFFICER SANITARY',T30,F10.0,F13.3)                       OUTP0180
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      R4=CPODA/AR                                                       OUTP0181
      R5=CPOHDA/AR                                                      OUTP0182
      R6=CBDA/AR                                                        OUTP0183
      R7=CHDA/AR                                                        OUTP0184
      R8=CODA/AR                                                        OUTP0185
      WRITE(IWRITE,128) CPODA,R4,CPOHDA,R5,CBDA,R6,CHDA,R7,CODA,R8      OUTP0186
  128 FORMAT(' CPO S.R.',T30,F10.0,F13.3/' CPO SANITARY',T30,F10.0,F13.3OUTP0187
     1/' CREW BERTHING',T30,F10.0,F13.3/' CREW SANITARY',T30,F10.0,F13.3OUTP0188
     2/' C.O. S.R.,CABIN & PANTRY',T30,F10.0,F13.3)                     OUTP0189
      R4=CSTDA/AR                                                       OUTP0190
      R5=OSDA/AR                                                        OUTP0191
      R6=WDA/AR                                                         OUTP0192
      R7=RLDA/AR                                                        OUTP0193
      R8=CLDA/AR                                                        OUTP0194
      WRITE(IWRITE,129) CSTDA,R4,OSDA,R5,WDA,R6,RLDA,R7,CLDA,R8         OUTP0195
  129 FORMAT(' COMMISSARY STORES',T30,F10.0,F13.3/' OTHER STORES',T30,  OUTP0196
     1F10.0,F13.3/' WORKSHOPS',T30,F10.0,F13.3/' REPAIR LOCKERS',T30,   OUTP0197
     2F10.0,F13.3/' CHAIN LOCKER',T30,F10.0,F13.3)                      OUTP0198
      R4=UTDA/AR                                                        OUTP0199
      R5=SGDA/AR                                                        OUTP0200
      R6=ACDA/AR                                                        OUTP0201
      R7=XICDA/AR                                                       OUTP0202
      R8=AMDA/AR                                                        OUTP0203
      R9=PHDA/AR                                                        OUTP0204
      PDA=.1*AR                                                         OUTP0205
      R10=PDA/AR                                                        OUTP0206
      R11=WSDA/AR                                                       OUTP0207
      R12=VMXA/AR                                                       OUTP0208
      WRITE(IWRITE,130) UTDA,R4,SGDA,R5,ACDA,R6,XICDA,R7,AMDA,R8,PHDA,R9OUTP0209
     1,PDA,R10,WSDA,R11,VMXA,R12                                        OUTP0210
  130 FORMAT(' UPTAKES',T30,F10.0,F13.3/' STEERING GEAR & FINS',T30,    OUTP0211
     1F10.0,F13.3/' A/C & FAN SPACES',T30,F10.0,F13.3/' I.C. SPACES',T30OUTP0212
     2,F10.0,F13.3/' AUX MACHINERY SPACES',T30,F10.0,F13.3/' PILOT HOUSEOUTP0213
     3,CHARTROOM & CIC',T30,F10.0,F13.3/' PASSAGES',T30,F10.0,F13.3/' MOOUTP0214
     4ORING STATIONS',T30,F10.0,F13.3/' MAIN MACHINERY IN BOX',T30,F10.0OUTP0215
     5,F13.3)                                                           OUTP0216
```

```
      ARE=AREADH+AREAHL
      R1=ARE/AR
      HABSPC=XMFDA+CSDA+OSRDA+OHDA+CPODA+CPOHDA+CBDA+CHDA+CODA
      EXAR=AR-1.1*(HABSPC+ODA+CSTDA+OSDA+WDA+RLDA+CLDA+UTDA+ACDA+XICDA
     1+AMDA+PHDA+ARE+WSDA+VMXA)
      R2=EXAR/AR
      WRITE(IWRITE,131) ARE,R1,EXAR,R2
  131 FORMAT(' INPUT AREA',T30,F10.0,F13.3/' EXCESS AREA',T30,F10.0,F13.
     13/)
      WRITE(IWRITE,132)
  132 FORMAT(/' CREW SPECIAL INCLUDES SICKBAY,BARBERSHOP,MOVIE LOCKER, L
     1AUNDRY,AND SHIPS STORE'////)
      HABSPC=HABSPC*9.
      COEF1=HABSPC/(NOFF+NCPO+NENL)
      COEF2=WTG2/SHPM
      COEF3=VMB/SHPM
      COEF4=WTG1/ENCVOL
      COEF5=WFULLD/ENCVOL
      COEF6=WLSHIP/ENCVOL
      COEF7=CSTG4/TOTCST
      COEF8=CSTG7/TOTCST
      COEF9=CFULLD/DT
      WRITE(IWRITE,133) COEF1,COEF2,COEF3,COEF4,COEF5,COEF6,COEF7,COEF8,
     1COEF9
  133 FORMAT(' HAB VOL/MAN = ',F10.1,' CUFT/MAN'/' GR2WT/HP = ',F6.4,
     1' TONS/HP'/' MACH ROOM VOL/HP = ',F7.4,' CUFT/HP'/' GR1WT/ENCVOL =
     2 ',F7.5,' TONS/CUFT'/' WFULLD/ENCVOL = ',F7.5,' TONS/CUFT'/' WLSHI
     3P/ENCVOL = ',F7.5,' TONS/CUFT'/' GR4COST/TOTCOST = ',F6.3/' GR7COS
     4T/TOTCOST = ',F6.3/' VCG/D     = ',F6.3///)
C     REMOVE THE FOLLOWING 4 CARDS FOR AN UNRESTRICTED RUN
      IF(JNDEX.GT.5.OR.LNDEX.GT.5) GO TO 1000
      RETURN
 1000 WRITE(IWRITE,134) SHPM,SHPE
  134 FORMAT(/' WARNING--AFTER FIVE HPCALC ITERATIONS, SHPM AND SHPE FIX
     1ED AT ',F10.2,' AND ',F9.2///)
      RETURN
```

OUTP0253

END

APPENDIX C

SAMPLE OUTPUT

COAST GUARD SHASM SYNTHESIS MODEL 270 FT WMEC FOR EEZ MAY 76 DR S PT 76***

*****INPUT DATA*****

ARMAMENT,AIRCRAFT AND CARGO INPUTS

ITEM	CARGO WEIGHT	CARGO VCG	GROUP 7 WEIGHT	GROUP 7 VCG	AMMO WEIGHT	AMMO VCG	AIRCRAFT WEIGHT	AIRCRAFT VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 7 COST
GROUP 7	0.0	0.0	16.7	1.060	4.9	0.890	25.0	1.190	15.000	2000.	200.	301200.

ELECTRONICS INPUT

ITEM	GROUP 4 WEIGHT	GROUP 4 VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 4 COST
GROUP 4	90.0	1.000	25.000	887.	1239.	2157000.

MANNING INPUT

NO. OF OFFICERS = 13.   NO. OF CPOS = 10.   NO. OF ENLISTED MEN = 80.

COST INDICES INPUT

LABOR RATE = 5.80 DOLLARS/HR
GROUP 1 INDEX = 2.25
GROUP 2 INDEX = 2.18
GROUP 3 INDEX = 1.63
GROUP 5 INDEX = 1.84
GROUP 6 INDEX = 1.98

INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MATERIAL COSTS

MILITARY MISSION CONSUMABLES INPUT

NO. ENDURANCE DAYS = 20. WEIGHT AIRCRAFT FUEL = 91.0 VCG AIRCRAFT FUEL = 0.110

VEHICLE PERFORMANCE INPUT

MAX SUSTAINED SHP COMPUTED
SUSTAINED SPEED = 19.70 KTS
ENDURANCE SPEED = 12.00 KTS
ENDURANCE RANGE = 3030. MILES
PROP COEFF = 0.700

OPTIONS

MTYPE = 1
FREE SURFACE CORRECTION = 0.50 FT
DESIGN AND BUILDERS MARGIN = 0.150
LENGTH = 270.0 FT
MATERIAL = 1 1=STL,2=AL

MACHINERY TYPE SELECTION,SHIP SIZE OR MODERNIZED REQUIREMENTS OUTSIDE MODEL LIMITS.
INPUT MACHINERY DATA FOR MTYPE=3 OR JOPT=2

PROGRAM PROCEEDING TO NEXT INPUT CASE

COAST GUARD SWATH SYNTHESIS MODEL 24C PT REC FOR ELT MAY 76 ER 8 PT 76***

*****INPUT DATA*****

ARMAMENT,AIRCRAFT AND CARGO INPUTS

ITEM	CARGO WEIGHT	CARGO VCG	GROUP 7 WEIGHT	GROUP 7 VCG	AMMO WEIGHT	AMMO VCG	AIRCRAFT WEIGHT	AIRCRAFT VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 7 COST
GROUP 7	0.0	0.0	16.7	1.060	4.9	0.890	25.0	1.100	15.000	2000.	200.	301200.

ELECTRONICS INPUT

ITEM	GROUP 4 WEIGHT	GROUP 4 VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 4 COST
GROUP 4	90.0	1.000	25.000	887.	1239.	2157000.

MANNING INPUT

NO. OF OFFICERS = 13. NO. OF CPOS = 10. NO. OF ENLISTED MEN = 80.

COST INDICES INPUT

LABOR RATE = 5.80 DOLLARS/HR
GROUP 1 INDEX = 2.25
GROUP 2 INDEX = 2.18
GROUP 3 INDEX = 1.63
GROUP 5 INDEX = 1.94
GROUP 6 INDEX = 1.98

INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MATERIAL COSTS

MILITARY MISSION CONSUMABLES INPUT

NO. ENDURANCE DAYS = 20. WEIGHT AIRCRAFT FUEL = 91.0 VCG AIRCRAFT FUEL = 0.110

VEHICLE PERFORMANCE INPUT

MAX SUSTAINED SHP COMPUTED
SUSTAINED SPEED = 19.70 KTS
ENDURANCE SPEED = 12.00 KTS
ENDURANCE RANGE = 3000. MILES
PROP COEFF = 0.700

OPTIONS

HTYPE = 2
FREE SURFACE CORRECTION = 0.50 FT
DESIGN AND BUILDERS MARGIN = 0.150
LENGTH = 240.0 FT
MATERIAL = 1 1=STL,2=AL

*****OUTPUT*****

LENGTH	BEAM	DRAFT	DIAM	LSTRUT	TSTRUT	CWP	LBOX	BBOX	DBOX	DISPLACEMENT	SHPMAX	VSUS	SHPEND
240.0	81.50	29.37	16.70	193.00	7.20	0.542	213.00	81.50	13.00	3267.55	15278.42	19.70	2973.20

ELECTRIC PLANT CAPACITY/GEN = 750. KW

	WEIGHTS	VCG	WT/WFULLD	WT/WLSHIP	COST
WTG1	1361.2	33.276	0.479	0.552	4435366.
WTG2	440.1	22.375	0.155	0.179	12197838.
WTG3	127.6	49.856	0.045	0.052	2818457.
WTG4	90.0	57.372	0.032	0.037	3099681.
WTG5	245.1	38.439	0.086	0.099	4063828.
WTG6	183.8	50.487	0.065	0.075	3830624.
WTG7	16.7	60.814	0.006	0.007	430906.
WLSHIP	2834.1	35.051	0.867	1.000	40991840. = TOTAL COST
FUEL	253.2	8.392	0.077		
LUB OIL	20.3	47.619	0.006		
CREW	7.6	51.061	0.002		
PER EFF	4.4	51.061	0.001		
PER STR	28.4	21.406	0.009		
CARGO	0.0	0.0	0.0		
ARMC	4.9	51.061	0.001		
AIR CFT	25.0	63.109	0.008		
A/C FUEL	91.0	6.311	0.028		
WFULLD	3268.9	32.443			

A MARGIN ON KG OF 0.0 FT EXISTS ABOVE THE FULL LOAD KG VALUE GIVEN

NOTE 06% MARGIN INCLUDED IN WLSHIP AND COST ESTIMATES BUT NOT IN INDIVIDUAL WEIGHT GROUPS
OVERHEAD AND PROFIT ARE INCLUDED IN INDIVIDUAL WEIGHT GROUP COSTS
TOTAL COST INCLUDES A DESIGN COST OF 3386424. DOLLARS
A CONST SERVICES COST OF 1549607. DOLLARS
AND A MISC. ITEM COST OF 5178919. DOLLARS
MISC.ITEM COST INCLUDES CRI OUTFIT, SPARES, RETROFIT COSTS, AND ADMINISTRATIVE COSTS(RIO)

VOLUME HULLS,STRUTS&BOX = 390306. CU FT
VOLUME OF DECKHOUSE = 53503. CU FT

	VOLUME(CU FT)	VOL/ENCVOL
MACHINERY ROOM	40453.	0.091
TANKAGE	19660.	0.044
ARRANGEMENTS	383697.	0.865

TOTAL ARRANGEMENTS AREA = [illegible].
HULL ARRANGEMENTS AREA = 10301.
DHSE ARRANGEMENT AREA = 9965.

	AREA(SQ FT)	AREA/TOT AREA
OFFICE SPACE	379.	0.015
MESSING FACILITIES	1726.	0.060
CREW SPECIAL	436.	0.017
OFFICER B.Q.	900.	0.036
OFFICER SANITARY	156.	0.006
CPO B.Q.	400.	0.016
CPO SANITARY	80.	0.003
CREW BERTHING	1768.	0.070
CREW SANITARY	400.	0.016
C.O. B.R.,CABIN & PANTRY	493.	0.019
COMMISSARY STORES	303.	0.010
OTHER STORES	2106.	0.083
WORKSHOPS	1069.	0.042
REPAIR LOCKERS	165.	0.006
CHAIN LOCKER	40.	0.002
UPTAKES	200.	0.008
STEERING GEAR & FIN	2089.	0.083
A/C & FAN SPACES	343.	0.014
I.C. SPACES	215.	0.009
AUX MACHINERY SPACES	3706.	0.146
PILOT HOUSE,CHARTROOM & CIC	976.	0.039
PASSAGES	2529.	0.100
MOORING STATIONS	725.	0.029
MAIN MACHINERY IN DCK	[illegible]	[illegible]
[illegible] AREA	4326.	0.171
EXCESS AREA	0.	0.0

CREW SPECIAL INCLUDES SICKBAY,BARBERSHOP,MOVIE LOCKER, LAUNDRY,AND SHIPS STORE

ARR VOL/MAN = 559.2 CUFT/MAN
MACHWT/HP = 0.0200 TONS/HP
MACH ROOM VOL/HP = 2.4477 CUFT/HP
HULLWT/HULLVOL = 0.00307 TONS/CUFT
WFULLD/TOTVOL = 0.00737 TONS/CUFT
WLSHIP/TOTVOL = 0.00639 TONS/CUFT
GRACOST/TOTCOST = 0.076
GRPCOST/TOTCOST = 0.011
TCC/R = 0.565

COAST GUARD SWATH SYNTHESIS MODEL 24C FT MRC FOR RLT MAY 76 GT 8 FT 76***

*****INPUT DATA*****

ARMAMENT,AIRCRAFT AND CARGO INPUTS

ITEM	CARGO WEIGHT	CARGO VCG	GROUP 7 WEIGHT	GROUP 7 VCG	AMMO WEIGHT	AMMO VCG	AIRCRAFT WEIGHT	AIRCRAFT VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 7 COST
GROUP 7	0.0	C.0	16.7	1.060	4.9	C.890	25.0	1.100	15.000	2000.	200.	301200.

ELECTRONICS INPUT

ITEM	GROUP 4 WEIGHT	GROUP 4 VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 4 COST
GROUP 4	90.0	1.000	25.000	887.	1239.	2157000.

MANNING INPUT

NC. OF OFFICERS = 13. NO. OF CPOS = 1C. NO. OF ENLISTED MEN = 80.

COST INDICES INPUT

LABOR RATE = 5.80 DOLLARS/HR
GROUP 1 INDEX = 2.25
GROUP 2 INDEX = 2.18
GROUP 3 INDEX = 1.63
GROUP 5 INDEX = 1.84
GROUP 6 INDEX = 1.98

INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MATERIAL COSTS

MILITARY MISSION CONSUMABLES INPUT

NC. ENDURANCE DAYS = 2C. WEIGHT AIRCRAFT FUEL = 91.C VCG AIRCRAFT FUEL = 0.110

VEHICLE PERFORMANCE INPUT

MAX SUSTAINED SHP COMPUTED
SUSTAINED SPEED = 24.00 KTS
ENDURANCE SPEED = 12.0C KTS
ENDURANCE RANGE = 30C0. MILES
PROP COEFF = 0.700

OPTIONS

MTYPE = 3
FREE SURFACE CORRECTION = 0.50 FT
DESIGN AND BUILDERS MARGIN = C.15C
LENGTH = 240.0 FT
MATERIAL = 1 1=STL,2=AL

******OUTPUT******

LENGTH	BEAM	DRAFT	DIAM	LSTRUT	BSTRUT	CWP	LBOX	BBOX	DBOX	DISPLACEMENT	SHPMAX	VSUS	SHPEND
240.0	77.33	27.18	15.53	193.00	6.72	0.942	213.09	77.33	13.00	2853.38	38610.90	24.00	2848.30

ELECTRIC PLANT CAPACITY/GEN = 750. KW

	WEIGHTS	VCG	WT/WFULLD	WT/WISHIP	COST
WTG1	1232.4	32.007	0.496	0.578	4084324.
WTG2	274.3	12.141	0.110	0.129	23795440.
WTG3	121.3	47.955	0.049	0.057	2668830.
WTG4	90.0	55.184	0.036	0.042	3059681.
WTG5	226.1	36.974	0.091	0.106	3800220.
WTG6	172.9	48.562	0.070	0.081	3594545.
WTG7	16.7	58.496	0.007	0.008	430506.
WISHIP	2453.7	33.412	0.859	1.000	54191424. = TOTAL COST
FUEL	234.9	7.767	0.082		
LUB OIL	7.4	45.803	0.003		
CREW	7.6	49.114	0.003		
PER EFF	4.4	49.114	0.002		
FEF STR	28.4	20.384	0.010		
CARGO	0.0	0.0	0.0		
AMMO	4.9	49.114	0.002		
AIR CPT	25.0	60.703	0.009		
A/C FUEL	91.0	6.070	0.032		
WFULLD	2657.2	30.667			

A MARGIN ON KG OF 0.0 FT EXISTS ABOVE THE FULL LOAD KG VALUE GIVEN

NOTE DED MARGIN INCLUDED IN WISHIP AND COST ESTIMATES BUT NOT IN INDIVIDUAL WEIGHT GROUPS
OVERHEAD AND PROFIT ARE INCLUDED IN INDIVIDUAL WEIGHT GROUP COSTS
TOTAL COST INCLUDES A DESIGN COST OF 3721665. DOLLARS
A CONST SERVICES COST OF 1782819. DOLLARS
AND A MISC. ITEM COST OF 7213538. DOLLARS
MISC.ITEM COST INCLUDES CBI OUTFIT, SPARES, RETROFIT COSTS, AND ADMINISTRATIVE COSTS(RIO)

VOLUME HULLS,STRUTS&BOX = 360017. CU FT
VOLUME OF DECKHOUSE = 42469. CU FT

	VOLUME (CU FT)	VOL/ENCVOL
MACHINERY ROOM	24082.	0.060
TANKAGE	18109.	0.045
ARRANGEMENTS	360296.	0.895

TOTAL ARRANGEMENTS AREA =	23025.	
HULL ARRANGEMENTS AREA =	18306.	
DKHSE ARRANGEMENT AREA =	4719.	
	AREA(SQ FT)	AREA/TOT AREA
OFFICE SPACE	277.	0.012
MESSING FACILITIES	1726.	0.075
CREW SPECIAL	436.	0.019
OFFICER S.R.	949.	0.041
OFFICER SANITARY	156.	0.007
CPO S.R.	400.	0.017
CPO SANITARY	80.	0.003
CREW BERTHING	1760.	0.076
CREW SANITARY	400.	0.017
C.O. S.R.,CABIN & PANTRY	493.	0.021
COMMISSARY STORES	343.	0.015
OTHER STORES	1980.	0.086
WORKSHOPS	973.	0.042
REPAIR LOCKERS	145.	0.006
CHAIN LOCKER	40.	0.002
UPTAKES	700.	0.030
STEERING GEAR & PIBS	1962.	0.085
A/C & FAN SPACES	317.	0.014
I.C. SPACES	215.	0.009
AUX MACHINERY SPACES	3492.	0.152
PILOT HOUSE,CHARTROOM & CIC	910.	0.040
PASSAGES	2302.	0.100
MOORING STATIONS	725.	0.031
MAIN MACHINERY IN DCK	0.	0.0
INPUT AREA	4326.	0.188
EXCESS AREA	141.	0.006

CREW SPECIAL INCLUDES SICKBAY,BARBERSHOP,MOVIE LOCKER, LAUNDRY,AND SHIPS STORE

HAB VOL/MAN = 559.2 CUFT/MAN
GR3WT/HP = 0.0071 TONS/HP
MACH ROOM VOL/HP = 0.0237 CUFT/HP
GR1WT/ENCVOL = 0.00306 TONS/CUFT
WFULID/ENCVOL = 0.00710 TONS/CUFT
WLSHIP/ENCVOL = 0.00610 TONS/CUFT
GR4COST/TOTCOST = 0.057
GR7COST/TOTCOST = 0.008
VCG/D = 0.556

COAST GUARD SWATH SYNTHESIS MODEL 240 FT WSC FOR [illegible]***

*****INPUT DATA*****

ARMAMENT,AIRCRAFT AND CARGO INPUTS

ITEM	CARGO WEIGHT	CARGO VCG	GROUP 7 WEIGHT	GROUP 7 VCG	AMMO WEIGHT	AMMO VCG	AIRCRAFT WEIGHT	AIRCRAFT VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 7 COST
GROUP 7	0.0	0.0	16.7	1.060	0.9	0.890	25.0	1.100	15.000	2000.	200.	301200.

ELECTRONICS INPUT

ITEM	GROUP 4 WEIGHT	GROUP 4 VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 4 COST
GROUP 4	90.0	1.000	25.000	887.	1239.	2157000.

MANNING INPUT

NO. OF OFFICERS = 13. NO. OF CPOS = 10. NO. OF ENLISTED MEN = 80.

COST INDICES INPUT

LABOR RATE = 5.00 DOLLARS/HR
GROUP 1 INDEX = 2.25
GROUP 2 INDEX = 2.18
GROUP 3 INDEX = 1.63
GROUP 5 INDEX = 1.84
GROUP 6 INDEX = 1.98

INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MATERIAL COSTS

MILITARY MISSION CONSUMABLES INPUT

NO. ENDURANCE DAYS = 20. WEIGHT AIRCRAFT FUEL = 21.0 VCG AIRCRAFT FUEL = 0.110

VEHICLE PERFORMANCE INPUT
MAX SUSTAINED SPEED COMPUTED
MAX SUSTAINED SHP = 12000.
GROUP 2 WEIGHT = 281.0 TONS
SFC MAX POWER = 0.560 LBS/SHP-HR
SFC HALF POWER = 0.640 LBS/SHP-HR
ENDURANCE SPEED = 12.00 KTS
ENDURANCE RANGE = 3000. MILES
PROP AUX ELECT LOAD = 70.000 KW
PROP COEFFICIENT = 0.700
GROUP 2 COST = 10664656. DOLLARS
WEIGHT OF LUBE OIL = 5.3 TONS
PROPULSOR LOCATION = 1 1=HULL
PROPELLOR LENGTH = 35.00 FEET
PRIME MOVER LOC = 1 2=POD
MACHY SPACE DIMS (L X W X H) = 27.00 X 14.00 X 10.00 FEET

OPTIONS

STYPE = 3
FREE SURFACE CORRECTION = 0.50 FT
DESIGN AND BUILDERS MARGIN = 0.150
LENGTH = 240.0 FT
MATERIAL = 1 1=STL,2=AL

*****OUTPUT*****

LENGTH	BEAM	DRAFT	DIAM	LSTRUT	BSTRUT	CWF	LBOX	BBOX	DBOX	DISPLACEMENT	SHPMAX	VSUS	SHPEND
240.0	77.83	28.06	16.03	153.CC	6.EE	C.542	213.00	77.83	13.00	3013.13	32CC0.C0	22.67	2905.15

ELECTRIC PLANT CAPACITY/GEN = 750. KW

	WEIGHTS	VCG	WT/WFULLD	WT/WLSHIP	COST
WTG1	1273.3	32.514	C.485	0.581	4196495.
WTG2	283.0	12.333	C.108	C.129	10864656.
WTG3	122.6	48.716	0.C47	C.056	2659203.
WTG4	50.0	56.059	C.034	C.C41	3095681.
WTG5	230.0	37.560	C.088	C.105	3855610.
WTG6	175.1	49.332	0.067	C.C80	3643800.
WTG7	16.7	59.423	C.006	C.C08	432966.
WLSHIP	2519.4	33.861	0.835	1.000	38179040. = TOTAL COST
FUEL	331.8	8.017	C.110		
LUB OIL	5.3	46.529	C.002		
CREW	7.6	49.893	C.003		
PER EFF	4.4	49.893	0.001		
PER STR	28.4	20.792	C.009		
CARGO	0.0	0.0	0.0		
ARRC	4.9	49.893	C.002		
AIR CPT	25.0	61.665	C.008		
A/C FUEL	91.0	6.167	C.030		
WFULLD	3017.8	30.403			

A MARGIN ON KG OF 0.0 FT EXISTS ABOVE THE FULL LOAD KG VALUE GIVEN

NOTE D&B MARGIN INCLUDED IN WLSHIP AND COST ESTIMATES BUT NOT IN INDIVIDUAL WEIGHT GROUPS
OVERHEAD AND PROFIT ARE INCLUDED IN INDIVIDUAL WEIGHT GROUP COSTS
TOTAL COST INCLUDES A DESIGN COST OF 3103259. DOLLARS
A CONST SERVICES COST OF 1425275. DOLLARS
AND A MISC. ITEM COST OF 4860218. DOLLARS
MISC.ITEM COST INCLUDES OPI OUTFIT, SPARES, PETROPIT COSTS, AND ADMINISTRATIVE COSTS (BIO)

VOLUME HULLS,STRUTS&BOX = 368329. CU FT
VOLUME OF DECKHOUSE = 42655. CU FT

	VOLUME(CU FT)	VOL/ENCVOL
MACHINERY ROOM	25038.	C.061
TANKAGE	23011.	C.056
ARRANGEMENTS	362935.	C.883

TOTAL ARRANGEMENTS AREA = 23195.
HULL ARRANGEMENTS AREA = 18456.
HOUSE ARRANGEMENT AREA = 4739.

	AREA(SQ FT)	AREA/TOT AREA
OFFICE SPACE	277.	0.012
MESSING FACILITIES	1726.	0.074
CREW SPECIAL	436.	0.019
OFFICER S.R.	949.	0.041
OFFICER SANITARY	156.	0.007
CPC S.R.	400.	0.017
CPC SANITARY	80.	0.003
CREW BERTHING	1760.	0.076
CREW SANITARY	400.	0.017
C.O. S.R.,CABIN & PANTRY	493.	0.021
COMMISSARY STORES	343.	0.015
OTHER STORES	1985.	0.086
WORKSHOPS	1000.	0.043
REPAIR LOCKERS	145.	0.006
CHAIN LOCKER	40.	0.002
UPTAKES	0.	0.0
STEERING GEAR & FINS	1997.	0.086
A/C & FAN SPACES	324.	0.014
I.C. SPACES	215.	0.009
AUX MACHINERY SPACES	3573.	0.154
PILOT HOUSE,CHARTROOM & CIC	929.	0.040
PASSAGES	2320.	0.100
MOORING STATIONS	725.	0.031
MAIN MACHINERY IN BOX	0.	0.0
INPUT AREA	4326.	0.187
EXCESS AREA	886.	0.038

CREW SPECIAL INCLUDES SICKBAY,BARBERSHOP,MOVIE LOCKER, LAUNDRY,AND SHIPS STORE

HAB VOL/MAN = 559.2 CUFT/MAN
GR2WT/HP = 0.0088 TONS/HP
MACH ROOM VOL/HP = 0.7824 CUFT/HP
GR1WT/ENCVOL = 0.00310 TONS/CUFT
WBUILD/ENCVOL = 0.00734 TONS/CUFT
WLSHIP/ENCVOL = 0.00613 TONS/CUFT
GR4COST/TOTCOST = 0.081
GR7COST/TOTCOST = 0.011
VCG/D = 0.542

COAST GUARD SWATH SYNTHESIS MODEL 155 FT HEC   MAY 76 DE 8 FT 76***

******INPUT DATA******

ARMAMENT,AIRCRAFT AND CARGO INPUTS

ITEM	CARGO WEIGHT	CARGO VCG	GROUP 7 WEIGHT	GROUP 7 VCG	AMMO WEIGHT	AMMO VCG	AIRCRAFT WEIGHT	AIRCRAFT VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 7 COST
GROUP 7	0.0	0.0	6.0	1.060	3.5	0.890	9.0	1.100	10.000	0.	200.	430000.

ELECTRONICS INPUT

ITEM	GROUP 4 WEIGHT	GROUP 4 VCG	ELECT LOAD	AREA IN DECKHSE	AREA IN HULL	GROUP 4 COST
GROUP 4	4.0	1.000	10.000	300.	400.	350000.

MANNING INPUT

NO. OF OFFICERS = 4.   NO. OF CPOS = 4.   NO. OF ENLISTED MEN = 30.

COST INDICES INPUT

LABOR RATE = 5.80 DOLLARS/HR
GROUP 1 INDEX = 2.25
GROUP 2 INDEX = 2.18
GROUP 3 INDEX = 1.63
GROUP 5 INDEX = 1.84
GROUP 6 INDEX = 1.93

INDICES INCLUDE EFFECTS OF INFLATION AND SPECIAL MATERIAL COSTS

MILITARY MISSION CONSUMABLES INPUT

NO. ENDURANCE DAYS = 20. WEIGHT AIRCRAFT FUEL = 15.0 VCG AIRCRAFT FUEL = 0.110

VEHICLE PERFORMANCE INPUT

MAX SUSTAINED SHP COMPUTED
SUSTAINED SPEED = 15.00 KTS
ENDURANCE SPEED = 10.00 KTS
ENDURANCE RANGE = 2000. MILES
PROP COEFF = 0.700

OPTIONS

MTYPE = 3
FREE SURFACE CORRECTION = 0.50 FT
DESIGN AND BUILDERS MARGIN = 0.120
LENGTH = 155.0 FT
MATERIAL = 2 1=STL,2=AL

*****OUTPUT*****

LENGTH	BEAM	DRAFT	DIAM	LSTRUT	DSTRUT	CWP	LBOX	BBOX	DBOX	DISPLACEMENT	SHPMAX	VSUS	SHPEND
155.0	50.91	18.91	10.81	125.00	4.54	0.528	145.00	50.91	13.00	871.33	2604.83	15.00	1124.40

ELECTRIC PLANT CAPACITY/GEN = 500. KW

	WEIGHTS	VCG	WT/WFULLD	WT/WISHIP	COST
WTG1	299.8	24.943	0.385	0.467	1367751.
WTG2	50.2	17.504	0.064	0.078	9324571.
WTG3	79.2	38.327	0.102	0.123	1639715.
WTG4	4.0	43.759	0.005	0.006	409650.
WTG5	102.9	29.319	0.132	0.160	1932933.
WTG6	99.6	38.509	0.128	0.155	1972131.
WTG7	6.0	46.385	0.008	0.009	518204.
WISHIP	718.6	29.100	0.824	1.000	22226736. = TOTAL COST
FUEL	107.4	5.403	0.123		
LUB OIL	3.8	36.320	0.004		
CREW	2.8	39.946	0.003		
PER SPP	1.6	38.946	0.002		
RES STR	10.5	15.653	0.012		
CARGO	0.0	0.0	0.0		
AERO	3.5	38.946	0.004		
AIR CPT	9.0	48.135	0.010		
A/C FUEL	15.0	4.813	0.017		
WFULLD	872.1	25.920			

A MARGIN ON KG OF 0.0 FT EXISTS ABOVE THE FULL LOAD KG VALUE GIVEN

NOTE D&B MARGIN INCLUDED IN WISHIP AND COST ESTIMATES BUT NOT IN INDIVIDUAL WEIGHT GROUPS
OVERHEAD AND PROFIT ARE INCLUDED IN INDIVIDUAL WEIGHT GROUP COSTS
TOTAL COST INCLUDES A DESIGN COST OF 1331899. DOLLARS
A CONST SERVICES COST OF 869934. DOLLARS
AND A MISC. ITEM COST OF 2855999. DOLLARS
MISC.ITEM COST INCLUDES CNI OUTFIT, SPARES, RETROFIT COSTS, AND ADMINISTRATIVE COSTS (RIO)

VOLUME HULLS,STRUTS&BOX = 156625. CU FT
VOLUME OF DECKHOUSE = 10333. CU FT

	VOLUME(CU FT)	VOL/ENCVOL
MACHINERY ROOM	10602.	0.064
TANKAGE	6815.	0.041
ARRANGEMENTS	149541.	0.896

TOTAL ARRANGEMENTS AREA = 10479.
HULL ARRANGEMENTS AREA = 9339.
ERROR ARRANGEMENT AREA = 1140.

	AREA(SQ FT)	AREA/TOT AREA
OFFICE SPACE	97.	0.009
MESSING FACILITIES	952.	0.091
CREW SPECIAL	161.	0.015
OFFICERS S.R.	292.	0.028
OFFICERS SANITARY	48.	0.005
CPO S.R.	160.	0.015
CPO SANITARY	32.	0.003
CREW BERTHING	660.	0.063
CREW SANITARY	150.	0.014
C.O. S.R.,CABIN & PANTRY	291.	0.028
COMMISSARY STORES	316.	0.030
OTHER STORES	844.	0.081
WORKSHOPS	335.	0.032
REPAIR LOCKERS	195.	0.019
CHAIN LOCKER	40.	0.004
UPTAKES	200.	0.019
STEERING GEAR & PIPE	1108.	0.106
A/C & FAN SPACES	334.	0.032
I.C. SPACES	140.	0.013
AUX MACHINERY SPACES	1519.	0.145
PILOT HOUSE,CHARTROOM & CIC	452.	0.043
PASSAGES	1040.	0.100
MOORING STATIONS	300.	0.029
MAIN MACHINERY IN PCR	669.	0.064
INERT AREA	900.	0.086
EXCESS AREA	754.	0.072

CREW SPECIAL INCLUDES RECREAT,BARBERSHOP,MCPFF LOCKERS, LAUNDRY,AND SHIPS STORE

RAS VCL/RAS = 650.4 CUFT/MAN
GRWT/HP = 0.0193 TONS/HP
MACH ROOM VOL/HP = 0.0701 CUFT/HP
GPINT/ENCVOL = 0.00190 TONS/CUFT
GPELEC/ENCVOL = 0.00522 TONS/CUFT
GLSHIP/ENCVOL = 0.00030 TONS/CUFT
GRPCOST/TOTCOST = 0.019
GPTCOST/TOTCOST = 0.023
VCG/D = 0.592

APPENDIX D

NAVSHIPS HULL GROUP WEIGHT CLASSIFICATION OF 1965

Group 1 - Hull Structure

100 - Shell Plating and Planking
101 - Longitudinal and Transverse Framing
102 - Inner Bottom
103 - Platform and Flats Below Lowermost Continuous Deck
104 - Fourth and Lower Continuous Decks
105 - Third Deck
106 - Second Deck
107 - Main Deck and Hangar Deck
108 - Forecastle and Poop Decks
109 - Gallery Deck
110 - Flight Deck, Landing Platforms, Special Purpose Decks above Weather Deck
111 - Superstructure
112 - Foundations for Propulsion Plant Machinery
113 - Foundations for Auxiliary and other Equipment
114 - Structural Bulkheads
115 - Trunks and Enclosures
116 - Structural Sponsors
117 - Armor
118 - Aircraft Fuel Saddle Tank Structure
119 - Structural Castings, Forgings and Equivalent Weldments
120 - Sea Chests
121 - Ballast and Buoyancy Units, Fixed or Fluid
122 - Doors and Closures, Special Purpose
123 - Doors, Hatches, Manholes and Scuttles - Nonballastic
124 - Doors, Hatches, Manholes and Scuttles - Ballistic
125 - Kingposts and Support Frames
127 - Sonar Dome
128 - Masts, Towers, Tetrapods, and Service Platforms
150 - Welding, Riveting, and Fastenings
151 - Free Flooding Liquids

Group 2 - Propulsion

200 - Boilers and Energy Converters (Non-Nuclear)
201 - Propulsion Units
202 - Main Condensers and Air Ejectors
203 - Shafting, Bearings, and Propellers
204 - Combustion Air Supply System
205 - Uptakes (Smoke Pipes)
206 - Propulsion Control Equipment (Non-Nuclear)
207 - Main Steam System
208 - Feedwater and Condensate System
209 - Circulating and Cooling Water Systems
210 - Fuel Oil Service System
211 - Lubricating Oil System
212 - Nuclear Steam Generators
213 - Reactors
214 - Reactor Coolant System
215 - Reactor Coolant Service Systems
216 - Reactor Plant Auxiliary Systems
217 - Nuclear Power Control and Instrumentation
218 - Radiation Shielding (Primary)
219 - Radiation Shielding (Secondary)
250 - Propulsion Repair Parts
251 - Propulsion Operating Fluids

Group 3 - Electric Plant

300 - Electric Power Generation
301 - Power Distribution Switchboards
302 - Power Distribution System (Cable)
303 - Lighting System (Distribution and Fixtures)
350 - Electric Plant Repair Parts
351 - Electric Power Generator Fluids

Group 4 - Communication and Control

400 - Navigation Equipment (Non-Electronic)
401 - Interior Communication Systems and Equipment
402 - Gun Fire Control System
403 - Countermeasure Systems (Non-Electronic)
404 - Electron Countermeasure Systems (ECM)
405 - Missile Fire Control Systems
406 - ASW, Torpedo Fire Control Systems (Surface Ships)
407 - Torpedo Fire Control System (Submarine)
408 - Radar Systems
409 - Radio Communication Systems
410 - Electronic Navigation Systems
411 - Space Vehicle Electronic Tracking Systems
412 - Sonar Systems
413 - Electronic Tactical Data System
450 - Communication and Control Repair Parts
451 - Communication and Control Operating Fluids

Group 5 - Auxiliary Systems

500 - Heating System
501 - Ventilation System
502 - Air Conditioning System
503 - Refrigerating Spaces, Plant, and Equipment
504 - Gasoline, HEAF, All Liquid Cargo Piping, Oxygen, Nitrogen, and Aviation Lubricating Oil Systems
505 - Plumbing Installations
506 - Firemain, Flushing, Sprinkler, Washdown, and Salt Water Service Systems
507 - Fire Extinguishing Systems
508 - Drainage, Ballast, Trimming, Heeling, and Stabilizer Tank Systems
509 - Fresh Water System
510 - Scuppers and Deck Drains
511 - Fuel and Diesel Oil Filling, Venting, Stowage and Transfer Systems
512 - Tank Heating Systems
513 - Compressed Air System
514 - Auxiliary Steam, Exhaust Steam, and Steam Drains
515 - Buoyancy Control System
516 - Miscellaneous Piping Systems
517 - Distilling Plant
518 - Steering Systems
519 - Rudders
520 - Mooring, Towing, Anchor and Aircraft Handling Systems and Deck Machinery
521 - Elevators, Moving Stairways, Stores Strikedown, and Stores Handling Equipment
522 - Operating Gear for Retracting and Elevating Units
523 - Aircraft Elevators
524 - Aircraft Arresting Gear, Barriers, and Barricades
525 - Catapults and Jet Blast Deflectors
527 - Diving Planes and Stabilizing Fins
528 - Replenishment at Sea and Cargo Handling
550 - Auxiliary Systems Repair Parts
551 - Auxiliary Systems Operating Fluids, Gases, and Stabilizer Fluids

Group 6 - Outfit and Furnishings

600 - Hull Fittings
601 - Boats, Boat Stowage, and Handling
602 - Rigging and Canvas
603 - Ladders and Gratings
604 - Nonstructural Bulkheads and Nonstructural Doors
605 - Painting
606 - Deck Covering
607 - Hull Insulation
608 - Storerooms, Stowages and Lockers
609 - Equipment for Utility Spaces
610 - Equipment for Workshops, Laboratories, and Test Areas
611 - Equipment for Galley, Pantry, Scullery and Commissary
612 - Furnishings for Living Spaces
613 - Furnishings: Offices, Control Centers, Machinery Spaces
614 - Furnishings for Medical, Dental, and Pharmaceutical
615 - Radiation Shielding for Nuclear Support Facilities
650 - Outfit and Furnishings Repair Parts
651 - Outfit and Furnishings Operating Fluids

Group 7 - Armament

700 - Guns and Gun Mounts
701 - Ammunition Handling Systems
702 - Ammunition Stowage
703 - Special Weapons, Handling and Stowage
704 - Rocket and Missile Launching Devices (Surface to Air, Surface to Surface, and Sub-Surface)
705 - Rocket and Missile Launching Devices (Anti-submarine Warfare)
706 - Rocket, Missile, and Components Handling Systems
707 - Rocket, Missile, and Components Stowage
708 - Torpedo Tubes
709 - Torpedo Handling and Stowage
710 - Mine Handling Systems and Stowage
711 - Small Arms and Pyrotechnic Stowage
712 - Air-Launched Weapons Handling Systems
713 - Air-Launched Weapons Stowage
720 - Cargo Munition Stowage
745 - General Arrangement - Armament Drawings
750 - Armament Repair Parts
751 - Armament Operating Fluids